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ORIGINAL ARTICLES.

Sedgwick Museum Notes.

I.—Notes on the Genus *Trinucleus*.—Part II.

By F. R. Cowper Reed, M.A., F.G.S.

(PLATE XIX.)

(*Concluded from the August Number, p. 353.*)

5. *Comparison of Upper and Lower Surfaces of Head-shield.*

As above stated, the arrangement of the pits on the lower surface of the fringe is not invariably the same as that on the upper surface, and we may now examine the degree of correspondence or difference in the better-known British species.

In *T. fimbriatus*[1] there is only a single row of pits close to the margin on the outer band of the lower surface, and they lie below the radial grooves on the upper plate, but they correspond with the outermost row of pits in these sulci only. The upper surface has all the pits arranged in radial sulci (except near the genal angles where the sulci die out), and of these 5–6 rows of pits the outermost is the largest, the others being very shallow, but increasing in size at the genal angles. The lower surface has an inner band, which bears fine radial sulci corresponding in number to the pits of the marginal row and each holding 3–4 small pits: towards the genal angles the pits do not lie in sulci. These sulci and pits have no corresponding structures on the upper surface (Pl. XIX, Figs. 2, 2*a*).

In *T. hibernicus*[2] there are no definite radial sulci on the outer band of the lower surface, but the pits in the rows are radially arranged and more or less fused in front, though at the sides they become quite separated and isolated in two distinct rows. These two rows correspond with the second and third rows on the upper surface, which has three rows of pits in front fused into short deep radial sulci; laterally these radial sulci only show two pits, and these approach one another more and more towards the genal angles till at last they fuse into one. The inner band of the lower surface has a single row of large pits corresponding in number to those of the outer band, but not represented at all on the upper surface (Pl. XIX, Figs. 1, 1*a*).

These two species show, therefore, very considerable differences in the pits of the upper and lower surfaces of the fringe.

[1] Salter, in Murchison's Silur. Syst., p. 660, pl. xxiii, fig. 2; McCoy, Syn. Pal. Foss. Woodw. Mus., p. 146, pl. 1E, fig. 16.

[2] Reed, Geol. Mag., Dec. IV, Vol. II, p. 52, Pl. III, Figs. 2–7, 1895.

T. Murchisoni[1] has the outer band of the lower surface furnished with primary radial sulci holding three pits, and shorter marginal secondary radial sulci are intercalated regularly between them and in front hold two pits but laterally only one pit. On the upper surface there is a corresponding number of primary and secondary sulci, but the primary ones hold four pits and the secondary ones two pits. These sulci on both surfaces extend right back to the genal angles. The inner band of the lower surface bears close behind the strong 'girder' in front a single concentric row of much larger pits agreeing in number and position only with the primary sulci; laterally towards the genal angles this single row splits into two rows of minute pits. It appears that the fourth or innermost row of pits in the radial sulci on the upper surface corresponds with this anteriorly single but posteriorly double row of large pits on the lower surface (Pl. XIX, Figs. 3, 3*a*).

In specimens of *T. Etheridgei*,[2] Hicks, from Scolton there is a very similar development of pits in the fringe to that in *T. Murchisoni*. The outer band of the lower surface bears in front primary radial sulci with three small pits in each, and between each pair of primary sulci there is a shorter marginal sulcus intercalated holding two pits as in *T. Murchisoni*; but laterally there is an absence of these shorter sulci, and the primary sulci nearly die out, while the pits in them become larger and more isolated. Near the genal angles a few of the shorter intercalated radial sulci reappear. On the upper surface there are similar primary and secondary radial sulci, the former holding 3–4 pits and the latter 1–2 pits. The sulci tend to die out posteriorly and the pits become more isolated, those of the first row becoming larger than the others. The short secondary radial sulci are wedged in on the margin in such a way as to seem to branch off from the side of the primaries in a Y-shaped manner, but they do not seem to originate from a true bifurcation of the primaries as Hicks' figures indicated. The inner band of the lower surface bears only one concentric row of large isolated pits fewer in number than the sulci, with a few smaller additional ones inside near the genal angles.

None of the specimens of the interesting species *T. Gibbsi*, Salter, which I have seen show the characters of the lower surface distinctly, and Salter[3] did not describe it. But as far as is known it seems to agree with the upper surface, which is wider in front than at the sides or posteriorly, and bears radial grooves holding 3–4 pits; these grooves decrease in length laterally as the fringe narrows, the pits in them being reduced to two and ultimately to one. There is only a small expansion of the fringe at the genal angles, with a few additional pores inside the main sulci.

In *T. subradiatus*[4] the pits in the two rows on the outer band of the lower surface are of equal size at the sides and alternate in the rows, but the pits are smaller in front in the second row; they are larger and deeper than those on the broad inner band, which decrease in size and depth to the inner edge. These small pits on the inner

[1] Salter, Mem. Geol. Surv., vol. iii, p. 515, pl. xiB, fig. 4.
[2] Hicks, Quart. Journ. Geol. Soc., vol. xxxi, p. 182, pl. ix, fig. 6, 1875.
[3] Salter, Mem. Geol. Surv., vol. iii, p. 516, pl. xii, fig. 10.
[4] Reed, Mon. Girvan Trilob. (Palæont. Soc.), pt. i, p. 12, pl. ii, figs. 1–6.

band are not arranged in regular concentric rows, but are placed in front in distinct radial lines with an irregular row of larger pits just inside the girder. Seven or eight pits in a line can be counted in front, but laterally they are indistinct, except along the inner edge, which shows very fine closely set shallow short radial grooves, each holding 2–3 very minute pits. The upper surface corresponds with the lower in the arrangement and development of the pits, as I have elsewhere described.

T. Lloydi, according to Salter's careful description (op. cit. supra), also appears to have the upper and lower surfaces of the fringe agreeing in their characters.

In *T. concentricus*,[1] though no strong girder is developed, there are some interesting features in the lower plate.

Two specimens of the lower plate of this species from the Utica Slate of Cincinnati show the first row of pits lying on the horizontal outer band; all the other rows lie on the concave inner band. Of these there are 2–3 concentric rows behind the first one in front of the glabella and 4–5 round the cheeks. The pits in the first row are rather smaller and more numerous than those in the second row; and the pits in all the rows alternate except in the case of the two innermost rows, the fifth row having originated by division of the fourth one and the pits therefore lying radially. On the upper surface of the fringe of this form the two outermost rows tend to be radial and also more or less fused together in front but not at the sides. This feature is also seen in a specimen from the Hudson River Group.

In British specimens attributed to *T. concentricus* we do not find always complete agreement with the above American examples, and it must be remembered that the species was first described in America by Eaton, so that the transatlantic examples must therefore be regarded as typical.

The Onny River specimens appear to approach the American somewhat closely as regards the fringe, but are not identical. A large series of examples from the Onny River have been examined, and in many cases they have the shell preserved. The upper and lower plates of the fringe are separated, as described above, and the relations of the pits on the two surfaces can thus be directly observed. On the lower plate the pits in the first row are smaller and usually about one and a half times more numerous than those in the second row, and where this is most marked all the radial arrangement is lost, but there are never any radial sulci. The pits of both the second and third rows are larger than those of the first row; those of the third row are rather smaller than those of the second row in front, but at the sides become equal.

The bending up of the inner band is well marked in front behind the second row, but with the decrease in the strength of the girder laterally the differentiation of the inner band dies out, and in section the fringe is here gently biconvex. There is a fourth row of pits alongside the cheeks, splitting into two rows at about the

[1] Eaton, Geol. Text-book, 1834, p. 34, pl. i, fig. 2.

middle, but joining up again into one near the genal angles. Occasionally a sixth row is developed inside. These three innermost rows have the pits radially arranged, but the others show no distribution into regular radial lines, being mostly alternate in successive rows.

The rows and pits in the upper plate of the fringe correspond with those on the lower, but in front of the glabella a radial alignment of the pits is often noticeable. The increase in the number of the pits in the outermost row takes place by intercalation at the sides and somewhat irregularly, so that the pits are unevenly spaced. The pits of the second and third rows are larger, subequal, hexagonal, and alternate, except just in front of the glabella. The fourth, fifth, and occasionally sixth rows are of successively smaller pits, and show a decided radial arrangement nearly all the way round. These features are clearly developed in the smallest specimens which I have seen, one of which measures across the fringe only 7 mm.

In specimens from Pwllheli the inferior plate has the concentric ridge between the third and fourth rows nearly as strong as the girder between the second and third, and the differentiation of the plate into an outer and inner band is obscure. The pits in the four outer rows are radially arranged, but those in the two outermost rows are smaller, and tend to lie in grooves in front. Towards the genal angles there are some extra pits intercalated in the first row, more or less destroying the radial lines, and the pits in the third row become larger. A fifth row is inserted laterally alongside the cheeks.

On the upper plate there are four rows of pits of equal size and at equal distances apart, arranged in weak radial grooves, and a fifth row is inserted laterally. The correspondence, therefore, in this form between the upper and lower plate is complete, and the regularity of the radial arrangement in weak grooves is a marked feature, distinguishing it from the Onny River specimens.

In the specimens of *T. concentricus* from Dinas Mowddy, which Salter[1] termed var. *Caractaci*, and McCoy[2] labelled *T. gibbifrons*, the lower plate has the same general characters as those from Pwllheli, but in the upper plate a few smaller pits intercalated in the first row interrupt the regularity of the radial arrangement of the four main concentric rows.

The specimens of *T. concentricus* from Allt y Anker and Rhiwargor have a strong girder inside the two outermost rows on the lower plate, while in the upper plate there are regular radial grooves in which lie the pits of the four concentric rows, and all the pits are of equal size, except in a few cases in which those of the first row are rather smaller.

T. favus,[3] which is marked by the unusual outline of the fringe, has the pits in the outermost row of the lower plate more numerous, rather smaller, and more closely placed than those in the second and third rows. All these three rows have their pits increasing in size on each side of the middle line, especially near the anterior lateral angles

[1] Salter, dec. vii, pl. vii, p. 6.

[2] McCoy, Brit. Pal. Foss., p. 145.

[3] Salter, Mem. Geol. Surv., vol. ii, pt. i, p. 350, pl. ix, fig. 3; vol. iii, p. 517, pl. xiii, fig. 9; dec. vii, pl. vii, p. 6.

of the fringe, but they decrease again in size towards the genal angles. Thus the largest pits are found near the frontal angles. A fourth row of smaller pits follows inside the third row, and two short rows are inserted at the anterior angles of the cheeks. The pits in the rows alternate at the sides, but are more or less radial in front.

On the upper plate there is a similar development of pits, and in the front part of the fringe the radial arrangement of the pits of the four concentric rows and their gradual increase in size to the lateral angles are well seen, but further back the radial arrangement is lost and they alternate. A fifth, sixth, and occasionally a seventh row, all of smaller pits, are developed inside at the angles, as on the lower plate, and more small ones at the genal angles, where the regularity of position is lost.

The Tyrone examples of *Trinucleus*, which have been referred to varieties of *T. concentricus* by various authors since Portlock divided them up into several species, show special features of interest and some peculiar characters. In only a few cases is the lower plate of the fringe known, and the association of upper and lower plates is often uncertain.

The specimen (now in Jermyn Street Museum) figured by Portlock[1] as intermediate between his *T. elongatus* and his *T. Caractaci* shows the cast of the lower lamella of the fringe in position with the head-shield. There is a single row of pits on the outer band outside the girder; a second row immediately inside the girder has its pits as large and in the same radii as those of the first row, and continues regularly back to the base of the genal spines. A third row is only developed from the front of the cheeks backwards, and the pits alternate. A fourth row of small pits is present at the sides only. But in the slightly re-entrant angle between the projecting anterior end of the glabella and the cheeks there are 3–4 partly fused minute pits in 5–6 short radial lines, while at the genal expansions there are, as usual, large irregularly distributed pits.

The specimen figured by B. Smith[2] from Tyrone as *T. Portlocki* (which according to Salter[3] is a variety of *T. concentricus*, including Portlock's *T. Caractaci* and *T. latus*) is the cast of a lower plate and has identical characters with the above.

The upper plate of *T. elongatus* represented by Portlock (op. cit., pl. 1B, fig. 7) shows strong radial sulci in front, holding three pits in a line, but the sulci and regularity of arrangement are lost at the sides, where the pits of the three concentric rows are alternate and are reinforced by a fourth inner row, while at the genal expansions six or seven short concentric rows of smaller pits are inserted.

In *T. Portlocki*, as represented by numerous specimens from Tyrone, the lower plate has only one row outside the girder, as in *T. elongatus*, and as far as its other characters are known seems to be indistinguishable from it. The upper plate of the fringe which was preserved in the type, and from which its characters were summarized by Salter "punctis ad frontem subradiatis et in ordines 3 contractis", shows four concentric rows of pits in well-marked regular radial lines, with only three rows

[1] Portlock, Geol. Rep. Londond., pl. 1B, fig. 6.
[2] Fearnsides, Elles, & Smith, op. cit., pl. viii, fig. 1.
[3] Salter, dec. vii, pl. vii, p. 6.

just in front of the glabella owing to its encroachment on the fringe. The pits, which are of subequal size (except in the third in front, which is there smaller), are sunk in somewhat indefinite radial sulci in front; all the pits become larger laterally and posteriorly, with a loss of the regular radial arrangement by the intercalation of pits in the first row, and are mostly alternate. At the genal expansions many much smaller pits are developed inside the main rows. Thus the fringe seems identical with that of *T. elongatus*.

Smith's var. *arcuatus* (op. cit., p. 122, pl. viii, figs. 5, 6) is imperfectly known and somewhat unsatisfactorily defined, but it has no close relation with *T. fimbriatus* of Murchison, as Portlock thought, if it is the form mentioned by him as intermediate between his *T. latus* and this species. In the so-called var. *expansus* (Smith MS.) the lower surface of the fringe is unknown, and on the upper plate there are (as in var. *arcuatus*) only 2–3 pits in the radial grooves in front, but the radial arrangement and grooves are lost at the sides; an additional row of small pits is here inserted between the first and second, and in all three rows the pits finally alternate, but the pits do not increase so markedly in size when the rows are traced posteriorly as they do in *T. Portlocki*, and the pits which are developed on the genal expansions are smaller, closer together, and more numerous.

The characterization of the fringe of these Tyrone forms is not marked, and the separation of the varieties from one another by this means is not obvious. It appears probable that they are not fixed or well-established varieties, but merely individual variations of one extremely unstable species, as will be further discussed in the sequel.

Passing to *T. Nicholsoni*,[1] which has been shown elsewhere to be allied to *T. concentricus*, we note that the outer band of the inferior plate of the fringe bears two rows of equal radially arranged pits, while the inner concave band behind the well-marked girder bears two rows of pits in front, increasing to three rows at the sides. All these inner rows have their pits arranged in the same regular radial fashion and on the same radii as those on the outer band, and are all of equal or subequal size (Pl. XIX, Figs. 4, 4*a*).

The upper plate has similarly four rows of pits arranged in depressed regular radial lines, but not in distinct sulci, with a fifth inner row inserted at the base of the cheek posteriorly. These pits correspond with those on the lower lamella, and their arrangement agrees precisely.

T. seticornis.—The British forms attributed to this species show several variations of more or less importance in the character of the fringe both on the upper and lower plates.

In specimens from Rhiwlas the lower plate shows two regular rows of equal-sized pits, not lying in sulci but radially arranged, on the outer band, while on the steeply inclined concave inner band there are 3–4 rows of smaller pits in distinct radial sulci corresponding in number, and these sulci have corresponding ones on the upper plate, but they are there less pronounced and they hold five pits in front of the glabella and 6–7 at the sides.

In specimens from Applethwaite (Coniston Limestone) the two

[1] Reed, GEOL. MAG., Dec. V, Vol. VII, p. 212, Pl. XVI, 1910.

outer rows of pits on the lower plate, which are separate and radially arranged at the sides, approach one another in front and fuse into one row, so that the girder has here only a single row of pits outside it. The pits on the inner concave band are arranged in three or more rows and in radial lines equal in number to the pits on the outer band, but do not lie in sulci.

In specimens from Norber Brow the two outer rows on the outer band fuse into one as in the Applethwaite form, but the pits of the third row (i.e. the first one inside the girder) become larger in front, and the radial lines of 3–4 pits slope inwards to the median axial line on each side.

In a specimen in the Jermyn Street Museum from Cynwyd, Merioneth, there is a similar reduction to a single row on the outer band in front, but on the concave inner band the 3–5 rows of small pits lie in sulci in front and half round the sides, while the sulci become obsolete further back. Just inside the girder at the sides of the cheeks at the base of these radial sulci there is intercalated a single detached row of larger pits in the same radii as those on the outer band.

Examples from Pusgill Beck show two regular continuous rows of pits radially arranged, but not in sulci, on the outer band, and in the same radii on the inner band lie 3–4 rows of smaller pits in shallow sulci extending round nearly to the base of the cheeks. On the upper plate the reverse is found, the inner rows having the pits lying isolated and not in grooves, while there are radial grooves in the outer part of the fringe each holding three pits, the outermost pit being additional, smaller, and not represented on the lower plate.

In the numerous specimens from the Redhill Stage of the Haverfordwest area the two rows on the outer band of the lower plate have the pits radially arranged and distinct, and not in grooves; the pits of the outer row are apt to be rather larger than those of the second row. On the inner concave band there are radial sulci agreeing in number with the pits on the outer band and holding 2–3 small pits. On the upper plate there are two outer rows of pits lying in short radial sulci, and inside them on the roll are rows of small pits radially arranged and corresponding to those on the lower plate but not placed in sulci. In some cases these inner radial lines of small pits are more numerous than the pits in the outer grooves.

The specimens from the Sholeshook Limestone agree with those from the Redhill Stage in the characters of the lower plate, except that the pits of the two rows on the outer band are equal in size, and on the inner band the radial sulci (which usually hold 3–4 pits) die out near the genal angles. In some individuals, however, we notice that the pits on the outer band lie in radial grooves and are more or less fused. An intermediate condition is found in specimens from the Slade Beds, for in them it is only the pits in the median front portion of the outer band which tend to lie in grooves, those at the sides being isolated (Pl. XIX. Figs. 5, 5*a*).

The specimens from Tyrone attributed to *T. seticornis* by B. Smith [1]

[1] Fearnsides, Elles, & Smith, op. cit., p. 122, pl. viii. figs. 7, 8.

are of interest, for the lower plate of the fringe shows a narrow horizontal outer band bearing only one row of pits in front, which laterally by transverse division splits into two rows in regular radial lines. A strong girder separates off the concave inner band, which bears a corresponding number of regular radial sulci holding 2–3 pits, the sulci becoming weaker or obsolete near the base of the cheeks. The pits in these sulci are rather larger and fewer than we usually find in *T. seticornis*, and this is particularly the case with the corresponding pits on the upper plate, which do not lie in distinct sulci. The two outer rows on the upper plate are distinct at the sides, but fuse into one in front; the radial arrangement of the lower plate is preserved. This form by the reduction of the rows to one on the outer band is like *T. Bucklandi* from Girvan, and indeed is indistinguishable from young examples of it, but a similar type of structure in the fringe has been mentioned above in specimens of *T. seticornis* from Applethwaite, Norber Brow, and Cynwyd.

Examples of *T. seticornis* from Portraine possess a lower plate with two rows of large radial pits on the outer band, and behind the strong girder there is first a separate row of isolated pits and then three inner rows of smaller pits in radial sulci, both agreeing in number with the outer rows. The upper plate has no definite roll, but there are two marginal rows sunk in grooves with 4–5 inner rows of slightly smaller pits, all arranged in regular radial lines.

T. Bucklandi from the Sholeshook Limestone, which is doubtfully separable as a species from the *T. seticornis* of this horizon, has the 5–6 rows of radially arranged small pits on the inner band of the lower plate more or less fused and lying in radial sulci which are more numerous than the pits of the two rows on the outer band. The upper plate has the corresponding inner rows of small pits in the roll lying separate and not in radial grooves.

The better-known *T. Bucklandi* from Girvan [1] has only a single row of pits in front on the inferior plate outside the girder, but on each side this row splits into two rows of radially arranged pits, as Nicholson and Etheridge described.[2] These pits on the upper plate lie in sulci and are more or less fused, but the sulci die out on the posterior portions of the fringe. The inner band on the lower plate bears radial lines of small pits sunk in sulci, with a single row of larger pits alternating with the radii intercalated at the base of the sulci just inside the girder. A similar row is sometimes present on the upper plate on which the radial rows on the roll do not lie in sulci.

In the largest examples from Girvan attributed to this species there is an abnormal development of pits, at any rate on the upper plate; for there are three rows of pits lying in the radial sulci near the margin instead of two, and between them and the base of the roll there are about three irregular rows of large, mostly alternating pits; the roll carries two or three concentric rows of more or less sunken radially arranged pits of equal size, and the radii are more numerous than the pits in the marginal rows.

[1] Reed, Mon. Girvan Trilob. (Palæont. Soc.), pt. i, p. 10, pl. i, figs. 10–14.

[2] Nicholson & Etheridge, jun., Mon. Silur. Foss. Girvan, fasc. ii, p. 193, pl. xiii, fig. 19.

In all these specimens of *T. seticornis* and *T. Bucklandi* the division of the fringe into an outer and inner band (which has been shown to be well marked on the lower plate by the girder in nearly every species, but is not similarly defined on the upper plate) is indicated by the marginal portion of the upper plate being horizontal and the inner portion more or less convex and steeply inclined so as to form a kind of roll under the front of the glabella and the cheeks dying out at the genal expansions. This roll, of course, corresponds to the concave inner band of the lower plate. Barrande [1] described and figured this feature in the Bohemian examples of *T. Bucklandi*, but in immature individuals he remarked that the differentiation was not developed.[2] Salter[3] stated that "the fringe is always steeply bent down and follows the declivity of the cheek without any change of direction, except in some specimens a gentle convexity".

The above remarks on the variation in the characters of the fringe in British examples of *T. seticornis* are not intended to suggest a classification based on these features alone. Any scheme of grouping together the various forms of this species must be based, if possible, on an aggregate of characters of all parts of the trilobite, and not on the fringe alone, although frequently we have to depend only on the head-shield. When the peculiarities of the glabella and cheeks have been discussed we shall be in a better position to make such an attempt. But the foregoing somewhat detailed account of differences in the fringe has been given to illustrate the amount of agreement or want of similarity which may exist between the upper and lower surfaces of the fringe of the same form. The general conclusion from these observations points to a fairly general and complete correspondence in the number of pits and rows on the two plates, but to frequent dissimilarity in the matter of radial sulci.

With regard to the connexion established by means of corresponding pits between the upper and lower surfaces in *T. seticornis*, it appears to be the case that there is generally no uninterrupted communication by means of the small pits on the roll and on the inner band, these pits being usually imperforate and merely indentations in the surface and substance of the plates; but the marginal pits and those at the genal expansions are perforated or connected by short tubes, as in *T. concentricus* from the Onny River.

Imperfectly known species.—There are several other British species which have been described and whose names have found their way into geological literature, but with regard to our knowledge of their fringe much is to be desired. In most cases figures have been given of the head-shield exhibiting only the characters of the upper surface of the fringe. Such are the following forms:—

(1) The species of *Trinucleus* from the Whitehouse Beds of Girvan described as *Trinucleus* sp. *b* by me in 1903[4] is now better known, and with regard to the fringe it shows on the upper surface two rows of radially arranged large pits which in front tend to sink into short

[1] Barrande, Syst. Silur. Bohême, vol. i, p. 621, pl. xxix, figs. 10–17.
[2] Ibid., pl. xxx, figs. 14–16.
[3] Salter, dec. vii, pl. vii, p. 7.
[4] Reed, Mon. Girvan Trilob., pt. i, p. 14, pl. ii, figs. 8, 8*a*; suppl., p. 160.

radial sulci; towards the genal angles the rows diverge somewhat and the pits are quite separate, and a short irregular row of a few pits is inserted at the posterior outer angles of the cheeks. The lower plate of the fringe of this species is not known.

(2) Another imperfectly known species as regards its fringe is *T. Sedgwicki*, Salter,[1] in which the upper surface of the fringe bears two outer rows of large pits sunk in radial sulci, and several inner rows of smaller pits "not strictly regular and more in number than the outer rows". As regards these features it suggests relations with *T. subradiatus*.

(3) The rare species *T. thersites*, Salter,[2] only found by him at Tramore, has a fringe with the upper surface possessing two regular concentric rows of an equal number of pits of equal size radially arranged, with an inner third row of fewer pits which are larger and widely spaced in front of and at the sides of the glabella, and are not here radially arranged, but posteriorly are more closely placed and no larger than the outer rows and divide into two and finally into three rows with their pits in radial lines near the genal angles and tending to lie here in shallow grooves and in the same radii as the outer row of pits. The lower surface shows a well-marked girder inside the two outer rows which correspond in development to those on the upper surface; there is a similar inner third row apparently continuous right round, and like the one on the upper surface dividing into two and then three rows posteriorly. This species has apparently never been figured.

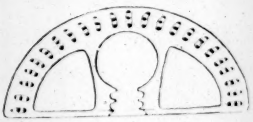
(4) *T. radiatus*, Murchison,[3] was founded on some fragments of head-shields showing a peculiar type of fringe described as follows:—"Marginal pores arranged on the front of the head in one or two rows; on the sides in long radiating lines. Buckler square, lateral spikes short." The examples of this species in the Jermyn Street Museum from Builth have in no case the complete fringe preserved, and only portions of the impression of the lower plate are present.

(5) *T. Ramsayi*, Hicks.[4] It has recently been pointed out by me[5] that this Trilobite is probably referable to the genus *Dionide*, and must certainly be removed from *Trinucleus*.

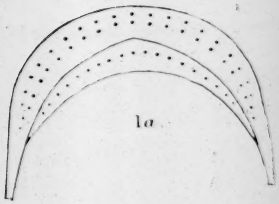
EXPLANATION OF PLATE XIX.

FIG. 1. *Trinucleus hibernicus*, Reed. Diagram of upper surface of fringe.
,, 1*a*. Ditto. Ditto of lower surface.
,, 2. *T. fimbriatus*, Murchison. Diagram of upper surface of fringe.
,, 2*a*. Ditto. Ditto of lower surface.
,, 3. *T. Murchisoni*, Salter. Diagram of upper surface of fringe.
,, 3*a*. Ditto. Ditto of lower surface.
,, 4. *T. Nicholsoni*, Reed. Diagram of upper surface of fringe.
,, 4*a*. Ditto. Ditto of lower surface.
,, 5. *T. seticornis* (Hisinger). Diagram of upper surface of fringe (Sholeshook form).
,, 5*a*. Ditto. Ditto of lower surface.

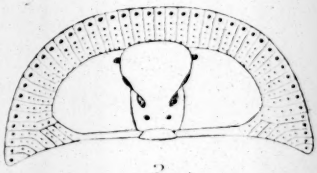
[1] Salter, Mem. Geol. Surv., vol. iii, p. 516, pl. xii, fig. 9.
[2] Salter, Dec. Geol. Surv., vol. vii, pl. vii, p. 7.
[3] Murchison, Silur. Syst., p. 660, pl. xxiii, figs. 3*a*, 3*b*.
[4] Hicks, Quart. Journ. Geol. Soc., xxxi, p. 183, pl. x, figs. 1, 2, 1875.
[5] GEOL. MAG., Dec. V, Vol. IX, p. 202, 1912.



1.



1a.



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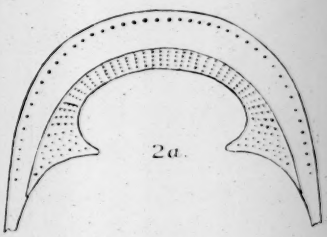

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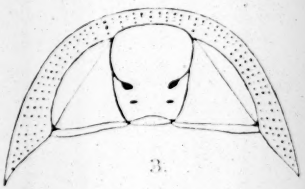

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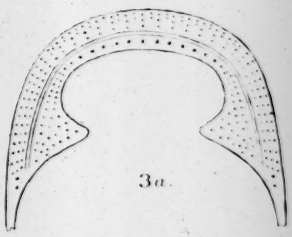

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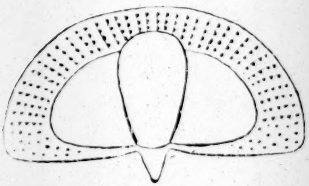

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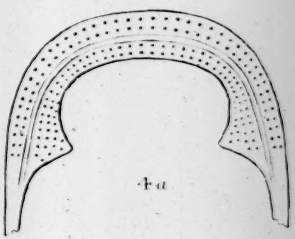

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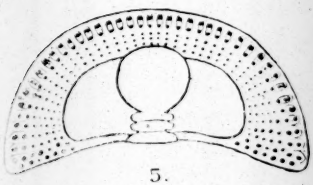

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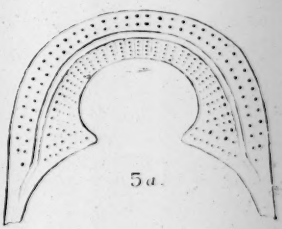


5a.

H. S. Brock del.

Structure of the 'fringe' around the head-shield of five species of *Trinucleus*.

II.—On *Archarenicola Rhætica*, sp. nov.

By A. R. Horwood (Leicester Museum).

(PLATE XXI.)

General Notes on the Horizon of Specimens A and B.

In the latter part of 1910 I was agreeably surprised upon the examination of some material from the Rhætic Black Shales at Glen Parva, Leicestershire, to detect a specimen which at the moment I recognized as new (specimen A).

Reference to this discovery, and to that of a second example in the Museum collections (specimen B), has already been made in brief[1] in the hope that, if other material of the kind existed, I might be apprised of it. So far, however, no further specimens have been obtained.

Specimen A, upon which I found the type, was not found in situ, but the burrows which undoubtedly belong to it are commonly found at 1 to 2 feet above the bone-bed, here the base of the Rhætics, overlying Tea-green Marl.

Specimen B was found by me amongst some old material in this Museum, which I have every reason to believe came from the now covered-up exposure of Rhætic beds at Spinney Hills, reported by the late Mr. W. J. Harrison, F.G.S., a former curator.[2] This specimen came from the bed numbered 5 in the section given, "sandstone 1 inch." On the other side are broken shells of *Avicula contorta*.

Review of Grouping of Fossil Polychætes.

Amongst Fossil Annelids so far only traces of Marine Polychætes have been detected. These have been subdivided into two groups—(*a*) *Tubicola* (Sedentaria), in which the parapodia are short and not used for swimming and in which the animal lives in a tube; (*b*) *Errantia* (Nereidæ), in which the animal is free-swimming and has a well-marked head, well-developed parapodia, with setæ used for locomotion. Some forms included here possessed powerful jaws.

There are really no authentic Palæozoic impressions, since those included in *Nereites*, *Nemertites*, *Myrianites*, *Nemapodia*, *Crossopodia*, *Phyllodocites*, *Naites*, etc., have been regarded as due to movements of Crustacea, Annelids, Gasteropods, and are not impressions of the cuticle at all.[3] This being so, the impressions here described must be regarded as belonging to a new order, and they belong to a different group, or Arenicolidæ.

The burrows included the genera *Scolithus*, *Arenicola*, *Histioderma*, *Planolites*, *Diplocraterion*, *Spirocolex*, *Scolecoderma*, some of which were described or grouped by Nicholson.[4] He considered, as did Nathorst, some of the trails or tracks were perhaps formed by Annelids, Crustaceans, or Molluses.

[1] Rep. Brit. Assoc. Portsmouth, Trans. Sections, 1911.

[2] "On the occurrence of Rhætic Beds in Leicestershire": Q.J.G.S., 1876, p. 212.

[3] A. G. Nathorst, "On the Tracks of some Invertebrate Animals and their Palæontological Significance": K. Svensk. Vetensk. Akad. Handl., Bd. xviii, xxi, 1881–6.

[4] H. A. Nicholson, "Contributions to the Study of the Errant Annelids of the Older Palæozoic Rocks": Proc. Roy. Soc., 1873, p. 288.

As to the first group the burrows, such as *Bilobites*, *Rusichnites*, *Arthrichnites*, *Protichnites*, *Climactichnites*, *Scolithus*, have been regarded also by Dawson[1] as due to the movements of various Invertebrates and not as Annelid burrows especially. *Sabellarites* he described as a new sand-tube, and *Buthrotrephis* as a true Fucoid from the Silurian.

The similarity between such impressions and those of the markings made by Molluscs and Crustacea had been pointed out by Professor McKenny Hughes,[2] so that a great clearance has been made of some of the old lumber that cumbered the ground in the domain of fossil Annelids.

Though this Annelid with its cuticular investment constitutes a new group, I think it unnecessary to make a third for its reception.

Notes on Specimen A. (Pl. XXI, Fig. 2.)

Size. Extreme length, 6 cm. Greatest width (upper end), 18 mm.; at centre, 16 mm.

Measurements between annuli. Distance between annuli, 1–2 mm. (5 to a centimetre).

The distance between the annuli varies irregularly; there are some shorter furrows between longer ones, especially in the anterior half, which is the underside of the raised or relief portion.

In *shape* it is a vermiform impression, slightly curved from below to the left. The impression being flattened, it is difficult to estimate the real diameter or girth of the animal originally. Compressed it forms a thick impression 3 mm.

The posterior portion has a stained outline, 5 mm. thick, on the right side, due to the exudation of animal matter or juices from the soft body preserved in the mud in some combination which is probably bituminous. A portion of the left posterior margin also shows the same character. Wherever the impression is preserved in the Black Shale the same greenish-brown external outline may be seen.

Segmentation. The term annuli has already been given to the transverse ridges that regularly cross the body. Whether it is possible to distinguish the definite arrangement of these annuli into segments, each consisting of so many annuli, cannot be determined owing to the manner of preservation. In *Arenicola*, of which I regard this fossil as a prototype, there are five annuli in each segment, one being larger than the rest and bearing the parapodia. As already noticed there is in specimen A a certain differentiation into two sizes, a large and a small annulus alternating. And to all appearance the appendages, chætigerous parapodia, are attached to the base of the larger annulus. But on this point it is impossible to speak with absolute certainty. In *Arenicola* there are three segments in front of the one bearing parapodia and one behind, and it is possible that the intercalation of three achætous segments is a new feature gained during the evolutionary progress of the genus, or that the apparent arrangement of alternate large and small segments is a variation of it.

Appendages. The body of *Arenicola* may be divided into three regions—an anterior with parapodia, without gills, a middle portion bearing both, and a posterior achætous portion.

The portion of the body to which specimen A may be said to correspond is the anterior non-branchiate portion. Though at first it appeared to be achætous, this portion does undoubtedly exhibit appendages which correspond to the notopodial setæ of *Arenicola*. If the capillary appendages on either side seen at intervals are notopodial setæ, the neuropodia must be invisible and beneath

[1] "On Burrows and Tracks of Invertebrate Animals in Palæozoic Rocks and other Markings": Q.J.G.S., 1890, p. 595.

[2] "On some Tracks of Terrestrial and Freshwater Animals": Q.J.G.S., 1884, p. 178.

the impression. There is, in fact, no sign of crotchets opposite the straight chætæ. These last are short, barely 5–6 mm. long, and are borne in fascicles so closely associated that they cannot be counted. They are not visible in every part, but are indicated by folds in the matrix, which may be taken to show their position. Within the broken portion of the body-surface in the posterior part are some detached chætæ of a similar nature. As a rule they bear a strong resemblance to the chætæ of *Arenicola marina*. It is not possible to distinguish any spathulate chætæ similar to those in *Arenicola*. As a whole they bear a resemblance to the parapodia of *Nereis*, but are not present on each annulus as in *Nereis*, and the annuli themselves do not show any trilobed divisions as in that genus. The appendages in fact most nearly approach those of *Arenicola*.

Surface. The surface of this fossil for 4·5 cm. of its length is the original cuticle of thick cells which now preserve only the form and arrangement of the external somites and annuli and the epidermal surface characteristics. The upper portion, 1·5 cm., is a cast of the inner surface of the cuticle, and possesses no surface features. As the anterior epidermis of this specimen is wanting, it is impossible to say whether it was like the lower part or not.

In *Arenicola* the anterior and middle part of the cuticle is divided up into well-marked contiguous polygonal areas which give it a wrinkled appearance. In the tail the cuticle is covered with prominent papillæ similar to the anterior arrangements in structure, and doubtless derived from similar definite polygons, originally, becoming rounded or sharply defined with age.

In the specimen A the cuticle is covered with raised papillæ which do not occur on the matrix itself, and are impressions of the papillæ found in *Arenicola* on the tail part. Whether this type had papillæ alone or on the anterior part remains to be investigated. But this worm must have presented in this and other characters already noted a very strong resemblance to the modern lugworm. The anterior third representing the inner surface retains traces in part of the inner tissue, belonging perhaps to the longitudinal muscles, but there is no structure preserved, as everything, except perhaps some chitinous chætæ, is replaced by the black shale matrix.

An exception may be made to the last statement perhaps in the case of the brown layer or ring surrounding the impression itself posteriorly. It is almost certain that this has been produced by a similar substance to the green or yellow pigment which is exuded in recent lugworms by the skin. It is thought by Ashworth to be a lipochrome. Another brown or black pigment insoluble in alcohol is like melanin in this respect, and may be derived from the yellow lipochrome. Indeed, Farroll showed that melanin could be due to chemical change in lipochrome under the influence of an acid. The further homology thus afforded by the probable identity between the brown stain and the pigment exuded by *Arenicola* makes the resemblance irresistible.

Head portion. In endeavouring to uncover part of the impression I found on the left side, in the posterior portion, an impression and counterpart of a terminal part of a similar annelid. This exhibits all the characters of the figured portion, and may be taken to be the head or anterior portion. No details as to the proboscis, peristomium, or other parts can be made out, as it is badly preserved, but there is a cast of what may be regarded as a protruding prostomium with a bifid apex, the lines of the straight stem or base of the prostomium being deeply impressed as two parallel lines, whilst the apex is in bas-relief; and as the other portion in alto-relievo does not show this, it is not possible to be absolutely certain as to the real outline of the structure. It is not exactly like that of *Arenicola*, but bears a considerable resemblance to it. The buccal papillæ of the proboscis, which is not clearly present, are not to be seen, so that it was not protruded. Had this worm been a *Nereis*, which the head portion might have indicated, it would have exhibited palps and tentacles and peristomial cirri, which *Arenicola* does not possess, and as there is no sign of these the homology in this instance again may be taken to be correct. It is fortunate indeed that this terminal portion came to hand, since it settles a point as to which otherwise there might have been difference of opinion.

Burrows. The shales in which this fossil (specimen A) occurs are commonly traversed by burrows which may, and in fact almost certainly must, have been the burrows of this Annelid. They are small in comparison, but have doubtless shrunk and become compressed since they were made. Most are horizontal, and if belonging to a worm of the *Arenicola* type, they belong to the horizontal part of the U-shaped burrow such as it makes in marine sands at the present day. They are irregular and not of great length, though the fragmentary material found can hardly be said to give an adequate idea of their length or true nature. Whether they were U-shaped or not is not clear.

Resemblance to a Myriapod, and difference. There is a superficial homœomorphy between this fossil and some fossil Myriapods. But there is no telson, no spiracles, no spines, the appendages are different (as are the annulation and segmentation). There are no ocelli, and the walking-feet of such fossils as *Acantherpestes* and *Euphoberia* are quite different. *Archarenicola* bears, indeed, on the whole a distinct Annelid character, whilst the fossils called Myriapods are quite distinct.[1]

The only resemblance lies in the fact that there is an outline which is regarded as due to the extrusion of the viscera, comparable with the brown zone that we suggest is due to staining by juices exuded by the Arenicola type of Polychæte.

Affinities. Having regard to the character of the head portion of specimen A and the parapodia, there can be no hesitation in placing this fossil in the group Phanerocephalæ, in which the prostomium is distinct, and the segmentation is of the same type.

As regards the sub-order to which it may be referred, there is no doubt that the absence of tentacles, palps, and peristomial cirri, and the simple nature of the parapodia which project, place it in the Scoleciformia, amongst which we find the family Arenicolidæ. The capillary setæ, absence of tentacles, palps, etc., place it in this last family. Whether it should belong to the caudate or ecaudate section is not demonstrable from the material so far to hand, but I should expect from its general characters in other respects that it belongs to the second.

Specimen B. (Pl. XXI, Fig. 1.)

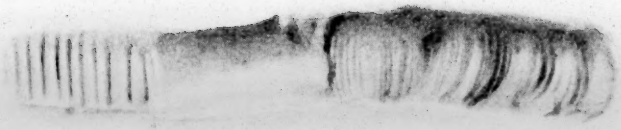
Size. Extreme length, 8·25 cm.; greatest width, 1 cm.

Measurements between annuli. The distance between the annuli is 2 mm. The annuli themselves measure as much, and the furrows between are deeply marked. This specimen is preserved in an indurated sandstone, and the impression is better marked anteriorly as regards annulation, having a less flattened appearance. At the posterior end the annuli are not so far apart. Anteriorly there are five to a centimetre, and each annulus is equidistant, except in one case, where it is 3 mm. distant from the next. For a great part the impression is covered by the matrix, which it is difficult to remove with advantage. Where it is uncovered elsewhere a black slickenside-like covering obscures the segmentation.

Surface. The anterior portion is an inside cast of the surface, except along the margin, and bears no papillæ. The posterior portion is covered by a black slimy covering, which may originally have been slimy bitumen, containing

[1] "Fossil Myriopods from the Middle Coal-measures of Sparth Bottoms, Rochdale, Lancashire": Geol. Mag., 1912, p. 74.

2



3

1

4

Archaeonicola rhatica, A. R. Horwood, sp. nov. Lower Rhætic: Glen Parva, Leicestershire.

juices exuded by the worm, in this case black. Underneath this, about the centre, are indications of the polygonal areas found anteriorly in *Arenicola*. A few papillæ are present here. Otherwise this specimen is very similar in surface characters to the type, specimen A.

Appendages. There are very few indications of appendages in this specimen, and they are similar in character to those in specimen A, but are only distinct on one side, the left, where they are distant. They are notopodial setæ without a doubt, but though only seen on one side there is no trace of neuropodial crotchets as in specimen A, and they may both therefore be regarded as viewed from the dorsal aspect.

Archarenicola, nov. gen.

An annulated Polychæte, with an impression of the cuticle bearing annuli of two sizes, possibly forming segments. The cuticular surface is covered in the type by epidermal papillæ, in the co-type by polygonal areas between the somites. The appendages are paired, on alternate annuli, consisting of capillary notopodial setæ. The head bears no appendages, but indications of a frilled prostomium. The impression is surrounded by a zone caused by exudations of the juices, as in the present-day *Arenicola*.

Archarenicola rhætica, sp. nov. (genotype).

Characters of the genus, based on specimen A (type) and specimen B (co-type).

Specimen A (Pl. XXI, Fig. 1). Horizon: Lower Rhætic—Black Shales. Locality: Glen Parva, Leicestershire.

Specimen B (Pl. XXI, Fig. 2). Horizon: Lower Rhætic—Black Shales. Locality: ? Spinney Hills, Leicestershire.

Both specimens are deposited in the palæontological collections of Leicester Museum, where they form the third type species of local origin.

I am greatly indebted to the discoverer of the type, Mr. A. J. S. Cannon, for the opportunity of seeing this and other Rhætic fossils of interest, and for much help in other ways. I have to thank Miss G. M. Woodward also for the care which she has taken in preparing the plate.

EXPLANATION OF PLATE XXI.

Fig. 1. *Archarenicola rhætica*, sp. nov. Specimen A. Lower Rhætic: Glen Parva. Nat. size.
,, 2. *Archarenicola rhætica*, sp. nov. Specimen B. Lower Rhætic: ? Spinney Hill, Leicestershire. Nat. size.
,, 3, 4. Burrows of *Archarenicola rhætica*, in Black Shale, Glen Parva. Nat. size.

III.—Notes on Laterite in Western Australia.

By Edward S. Simpson, B.E., F.C.S., Geological Survey of Western Australia.

(Communicated by permission of the Government Geologist of Western Australia.)

THE following notes on the laterites of Western Australia are the outcome of a careful study of the series of articles contributed to the Geological Magazine during the latter part of 1911 by Dr. L. Leigh Fermor, entitled "What is Laterite?" These deal with the

subject from the point of view of one having an intimate knowledge of Indian laterite, but not a first-hand acquaintance with those of other parts of the world. The present writer, during the last fifteen years, has devoted much time to the study of the laterite of extra-tropical Western Australia, both in the field and in the laboratory, and is therefore in a position to supplement some of the work of Dr. Fermor, whilst inclined to differ from him in some of his deductions.

Broadly speaking, the laterite of Western Australia may be divided into two classes—

(1) Primary Laterite (true laterite, high-level laterite), formed in situ out of soluble material derived from the weathering rock immediately underlying it.

(2) Secondary Laterite (lateritite, low-level laterite), composed largely of the mechanically transported fragments of primary laterite.

The study of the latter being dependent on and of secondary importance to the study of the former, it is the primary laterites which have been most closely examined, and will be dealt with almost exclusively in this article.

Primary laterite in Western Australia, and probably elsewhere, is a product of normal processes of weathering, accompanied by abnormal conditions of rainfall and denudation. It is not necessarily confined to tropical areas: immense deposits in this State are extra-tropical. It is simply confined to areas underlaid by suitable rocks, and subject to all three of the favourable conditions just mentioned.

By "suitable rocks" is meant rocks composed largely or wholly of metallic silicates, especially in this State, granite and greenstones of common types, as well as amphibolites, epidiorites, chlorite-schists, and other similar rocks.

By "normal processes of weathering" is meant the attack of the outcrops of such rocks with rain-water carrying atmospheric carbonic acid, the result being the formation of kaolin (crystalline $Al_2O_3 . 2SiO_2 . 2H_2O$), halloysite (amorphous $Al_2O_3 . 2SiO_2 . 2H_2O$), and quartz or hydrous silica, together with solutions of aluminium hydrate, titanium hydrate, ferrous carbonate, calcium carbonate, magnesium carbonate, manganous carbonate, etc.

The abnormal conditions of rainfall tending to produce laterite are such that the weathering rocks and any products are alternately saturated with water and then again completely desiccated.

A slow rate of denudation is essential.

Primary laterite is a true efflorescence, that is, a deposition on the surface of the ground of substances dissolved by underground water, brought to the surface by capillarity, and there deposited as solid matter owing to aeration and evaporation of the water.[1]

Primary laterite in Western Australia, wherever sunk through, is found to overlie an almost pure pipeclay, and this in turn a crystalline rock. Dr. Fermor holds kaolinization to be a process incompatible with laterite formation.[2] In Western Australia the processes are

[1] *Vide* E. S. Simpson, Bull. 6 of the Geol. Surv. of Western Australia, pp. 39, 78, 79. Published 1902.

[2] Geol. Mag., 1911, p. 459.

contemporaneous and inseparable from one another. Dr. Fermor writes thus:—

"When a rock breaks down into a *clay* hydrated aluminium silicate is to be regarded as the pure end product, all oxides being removed in solution. When a rock is converted into laterite, on the other hand, the reverse holds; aluminium and other silicates are decomposed, and the silica is removed in solution, presumably in the colloidal form, whilst the oxides of iron, aluminium, titanium, and manganese, which were relatively soluble under the clay-forming conditions, are relatively insoluble under laterite-forming conditions. The oxides of calcium, magnesium, sodium, and potassium are apparently soluble under both sets of conditions. I do not propose to advance here any reasons to account for these two diverse modes of alteration of rocks. . . ."

Such an apparently paradoxical postulate seems to require detailed explanation on the part of the author. Surely Dr. Fermor is putting the cart before the horse when he speaks of the concentrated accumulation of lateritic material as due to the leaching away of the non-lateritic products of weathering. The formation of an ordinary efflorescence of salt on the surface of salty ground, or of an efflorescence of gypsum or potassium vanadate on the surface of a brick are phenomena identical with the formation of laterite, but one does not explain them by saying that in the one case the insoluble sand and clay of the soil is dissolved away, leaving an accumulation of insoluble salt, or that in the other case the baked clay of the brick is dissolved away, leaving an accumulation of gypsum or vanadate of potash.

The same remarks indicate the absurdity of referring to a laterite as a true residual, or as a replacement of a rock, i.e. a deposit accumulating in the actual space originally occupied by the solid rock which has yielded the materials which compose the laterite. The primary laterites of Western Australia are deposited, like other efflorescences, outside the surface of the parent rock. Two typical sections are shown in the accompanying figure (p. 402).

Reverting to the question of the distribution of rainfall favourable to the formation of laterite, the extra-tropical portion of Western Australia may be divided into two provinces. One of these lies within 50 to 100 miles of the western coast, where the average annual rainfall is between 20 and 40 inches, distributed between well-defined wet and dry seasons. Typical laterite localities in this area are Mundaring and Greenbushes, the rainfall of which are—

	Mundaring. Inches.	Greenbushes. Inches.
Average annual rainfall . . .	41	37½
Average November to March .	2½	3
Average April to October . . .	38½	34½

The other province includes the Eastern Goldfields, and has no defined annual wet and dry seasons. The average rainfall is between 7 and 12 inches, one-quarter of which frequently falls in a single day, the usual intervening climatic conditions being intensely arid. As typical examples, Mulline, with an average of 11·2 inches, had a fall of 3·3 inches on one day in 1907; Coolgardie, with an

average of 9·4 inches, recorded nearly 4 inches in two closely following days of the same month. These are typical, not abnormal, rainfall conditions.

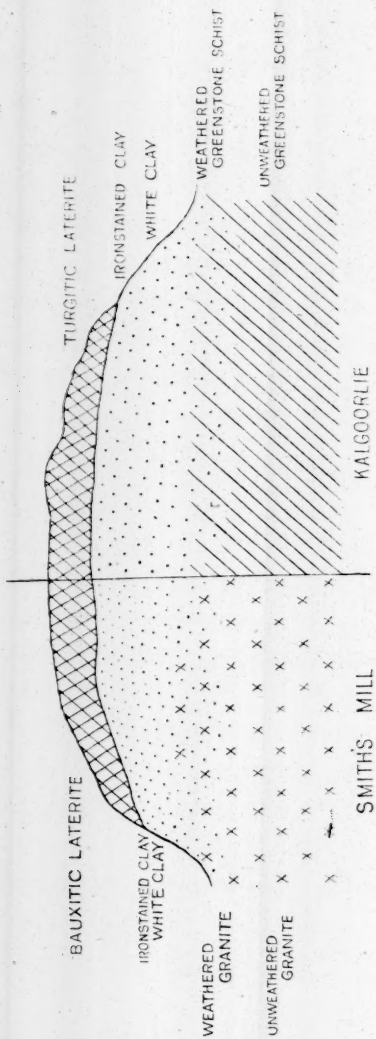


Diagram showing two typical examples of the mode of occurrence of primary laterites in Western Australia.

Although the climatic conditions in these two provinces are so very different, yet the result from the present point of view is identical, viz., short or long periods during which the surface rocks are saturated with meteoric water, alternating with long dry and hot periods, during which they are completely desiccated and the freshly-formed laterite

hardened. Such conditions seem to me to favour, if not indeed to be necessary to, the accumulation of laterite.

It would appear that the accumulation of laterite is a very slow process, and cannot take place where erosion is moderately rapid. It tends, therefore, to grow on well-defined peneplains, such as the 1,000 feet Darling Range peneplain, and on the upper very gentle slopes of valleys, where denudation is slow. Bare rock, clay, sand, and secondary laterite carrying sand and clay are found at lower levels. In Western Australia primary laterite is found chiefly between 500 and 1,500 feet above sea-level. Higher altitudes than 1,500 feet are rare within the extra-tropical parts of the State. They are usually devoid of laterite.

The climatic conditions favouring its formation and preservation having been dealt with, the details of its growth need elucidating. It has already been stated that laterite is an efflorescence resulting from normal weathering, the first stage in the process being the conversion of felspars into kaolin and the partial saturation of the sub-surface water with carbonates of iron, manganese, lime, and magnesia, with hydrous silica, titania, and alumina, and finally with alkali salts. With the advent of dry weather this solution begins to evaporate at the surface, and as it evaporates further supplies are brought to the surface by capillary action. A slow but appreciable movement of water from below to the surface goes on till the weathered rock is desiccated. Mere contact of this water with the atmosphere is sufficient to precipitate all the iron and manganese as hydrated peroxides, two important laterite constituents. Evaporation increases the speed of this precipitation, and at the same time leads to the precipitation of all the other substances dissolved in the water. Alumina and silica in the proportions Al_2O_3 to $2SiO_2$ are co-precipitated as colloidal halloysite (lithomarge of Fermor), $Al_2O_3 . 2SiO_2 . 2H_2O$. An excess of silica over this proportion seldom if ever occurs in the water, an excess of alumina is precipitated as hydrate, probably primarily as gibbsite, $Al_2O_3 . 3H_2O$. Titanium is precipitated as metatitanic acid, $TiO_2 . xH_2O$. During the growth of the laterite small amounts of sand and clay become mechanically included.

All the important constituents of laterite are thus accounted for. But in addition to these the evaporating water must have deposited at the same time alkali salts and carbonates and sulphates of lime and magnesia, compounds occurring only in traces in normal primary laterite. The history of the rock is evidently not yet complete. It must be continued over the dry season, during which the typical laterite materials are rendered practically insoluble by consolidation and desiccation, into the succeeding wet season. The soluble alkali, lime, and magnesia salts are then soon taken up by the rain-water and carried off in the streams. The laterite has then reached its final composition.

In structure West Australian laterites are almost always pisolitic, the typical form of an amorphous substance slowly growing by precipitation from solution. The nodules vary in size from that of a pin's head up to about 1 inch in diameter, the average being one-eighth to one-quarter of an inch. The spaces between the nodules

are partly filled with similar material to the nodules, partly unfilled. Rarely (e.g. Lone Hill, Kalgoorlie) some of the more ferruginous laterites are devoid of concretionary structure, whilst still containing numerous visible pores.

The composition of some typical laterites is given in the accompanying table :—

COMPOSITION OF WEST AUSTRALIAN PRIMARY LATERITES.

Locality.	Kalgoorlie. (1)	Kalgoorlie. (2)	Kalgoorlie. (3)	Kalgoorlie. (4)	Coolgardie.	Comet Vale.	Boogardie.	Smith's Mill.	Wongan Hills.	Mt. Baker.	Greenhearys Hill.
Fe_2O_3	78·38	75·41	79·41	62·67	80·02	79·01	73·81	10·02	19·08	35·54	39·80
Al_2O_3	9·92	12·29	5·97	12·76	4·32	?	?	46·70	44·66	31·14	36·74
Cr_2O_3	0·01	0·05	0·60	0·08	0·08	5·30	?	?	?	?	0·03
V_2O_5	0·40	0·45	0·65	0·15	0·55	?	?	?	?	?	0·23
MnO_2	0·07	0·41	0·07	0·35	0·13	?	?	?	?	?	0·06
MgO	0·35	none	1·56	0·99	trace	?	?	trace	trace	trace	0·15
CaO	none	none	none	none	none	?	?	trace	trace	0·16	0·10
TiO_2	2·01	2·55	3·10	6·00	6·06	?	?	0·59	3·10	4·33	1·98
SiO_2, Quartz	2·67	1·77	2·52	2·73	0·76	3·14	11·46	17·17	5·96	13·74	4·44
SiO_2, Combined					1·77						1·97
P_2O_5	trace	trace	trace	trace	trace	0·18	0·05	trace	trace	trace	trace
H_2O	6·00	7·05	6·89	14·46	7·06	?	2·86	25·37	27·02	15·40	14·93[1]
	99·81	99·98	100·77	100·19	100·75	?	?	99·95	99·82	100·31	100·43

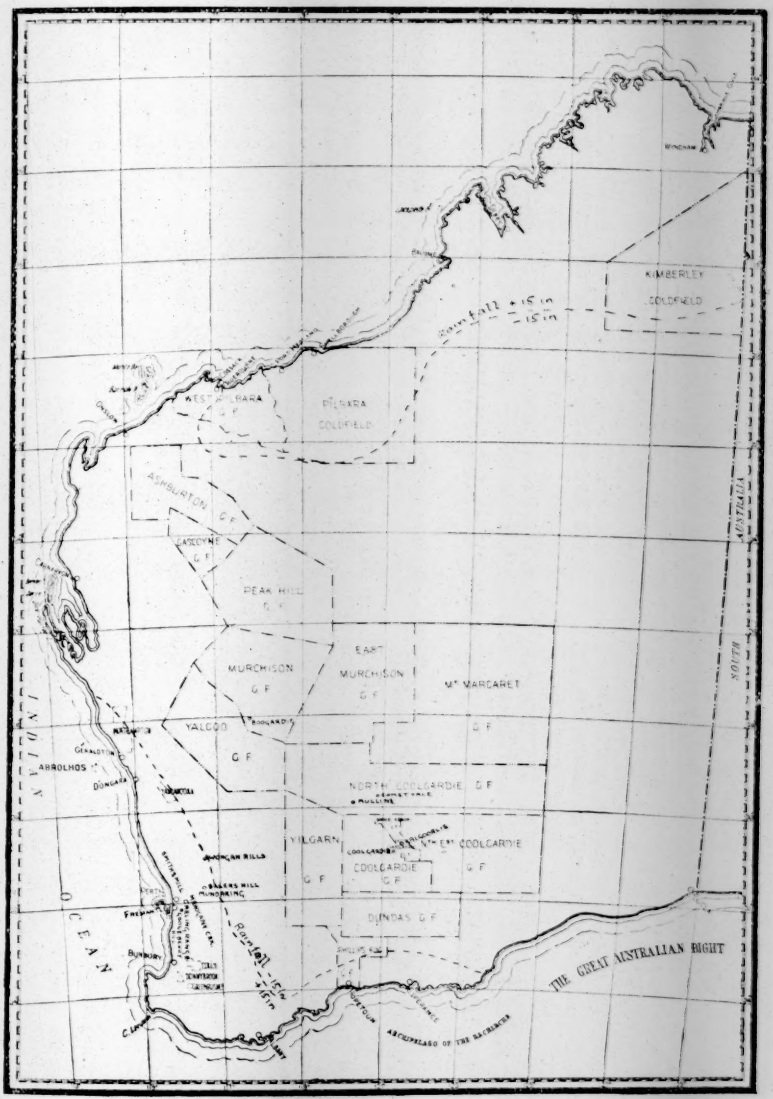
These analyses, though so many of them are incomplete, are an assistance in unravelling the mineral composition of the laterite.

The iron is undoubtedly present as limonite, $2\,Fe_2O_3 . 3\,H_2O$, in many of them, e.g., Kalgoorlie (4), Smith's Mill, and Wongan Hills. Turgite, $2\,Fe_2O_3 . H_2O$, is, however, just as common, particularly in laterites from the interior, such as Kalgoorlie (1), (2), and (3), and Coolgardie. Its presence, suspected from the results of the analyses, was readily confirmed by the decrepitation of the mineral when heated in a closed tube. Gothite, $Fe_2O_3 . H_2O$, and hæmatite are probably present at times. Wherever the laterite overlies greenstone an iron hydrate is the predominant constituent.

Solutions of these laterites in a mixture of sulphuric and hydrofluoric acids, prepared in a neutral atmosphere, are invariably capable of reducing potassium permanganate solution, usually in two distinct stages. For example, the Coolgardie laterite quoted above instantaneously reduced permanganate equal to 0·80 per cent of ferrous oxide, and more slowly (about 3 seconds) a further amount equal to 0·54 per cent ferrous oxide. This consumption of permanganate may be due to the presence of ferrous oxide, vanadium trioxide, or organic matter. No definite interpretation is at present possible, but the writer is inclined to consider that it is in small part due to the presence of a little ilmenite or magnetite, but more largely

[1] 1·20 per cent at 105°.

to the presence of organic compounds of iron. In this connexion it is worth noting that a series of small springs flowing out from beneath



Map of Western Australia, showing localities where laterite has been observed, and referred to in Mr. E. S. Simpson's paper.

the laterite at Mundaring gives rise to a stream which, near the laterite, was found (in 1909) to contain ferrous iron (1·32 grains

per gallon) and organic matter, together with insufficient inorganic radicles to satisfy the basic radicles. This water apparently contained organic compounds of iron.

Alumina is present in all the laterites, but most abundant in those overlying granite and other less ferruginous rocks. In the Wongan Hills and Smith's Mill samples it appears to exist as gibbsite, $Al_2O_3 . 3H_2O$, in other cases it is less hydrated, corresponding to bauxite, $Al_2O_3 . 2H_2O$, or diaspore, $Al_2O_3 . H_2O$.

Titanium oxide is always present in appreciable amounts, probably in the form of metatitanic acid, $TiO_2 . xH_2O$, for which no mineralogical name has yet been suggested. Experiments on the Coolgardie laterite showed it was not present, except in traces perhaps, as rutile or ilmenite. The titanium compound was found to be insoluble in warm dilute hydrochloric acid but soluble in fuming sulphuric acid.

Silica is present as (1) quartz, or rarely felspar, mechanically entangled, and (2) in combination in a form decomposed by strong hydrochloric acid, probably halloysite.

Only very small percentages of manganese oxide have been observed.

Chromium oxide has been detected in every case where it was looked for. It varied from a trace to 5·30 per cent. In the latter case it was almost wholly present as chromic hydrate, soluble in strong hydrochloric acid. A small proportion was present as chromite. It is probable that where the percentage of Cr_2O_3 rises above 0·1 per cent the underlying rock is of an ultra-basic type.

Notable amounts of vanadium were detected whenever looked for. The highest proportion noted was 0·65 per cent, V_2O_5 (?), in a turgitic laterite from Kalgoorlie. The form in which this constituent occurs in the rock is not yet determined. This is only one of many unsolved problems connected with this deeply interesting formation.

IV.—On the origin of certain Clay-bands in the Limestone of the Crich Inlier.

By H. C. Sargent, F.G.S.

Introductory.

In the Carboniferous Limestone of the Crich inlier in Derbyshire, there are numerous clay-bands or partings interbedded with the limestone which appear to throw considerable light on the geological history of the area.

These clay-bands vary in thickness from about 3 feet down to the thinnest possible parting between two beds of rock. Some of those between the higher beds are undoubtedly contemporaneous detrital sediments [1] and appear to indicate shallow-water conditions; others, though consisting of sedimentary material, were probably deposited along solution planes subsequently to the formation of the limestone;

[1] Many, perhaps all, of the tuffs of Derbyshire are sediments, but, to avoid ambiguity, the use of the word in this paper is confined to detrital deposits, the waste of a land-surface.

whilst a few of the thinnest partings consist for the most part of beautiful, minute, prismatic crystals of quartz without admixture of any 'clay-substance'. All these beds are comparatively thin, not exceeding an inch or two, as a rule, and often much less.

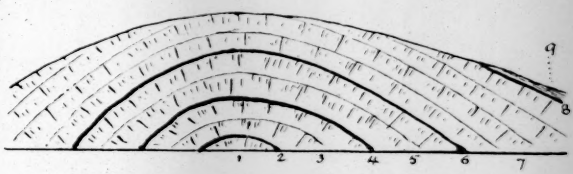
The object of the present paper is, however, to discuss the origin of the thicker clay-bands, which have already received a certain amount of attention at the hands of geologists, but which differ considerably in structure from any of the foregoing beds.

Field Relations.

The limestone of the Crich inlier forms part of the anticlinal fold which trends northward from Belper to Ashover, and its northern portion lies about 3 miles south-east of the main limestone *massif* at Matlock.

There are four distinct beds of these clays exposed in the inlier, and they may all be seen in the face of Cliff Quarry, situated under the summit of Crich Hill. The accompanying section shows their positions relatively to each other and to the limestone.

N.W. S.E.



Diagrammatic section through Crich Hill.

		Feet.
9.	Thin-bedded blue limestone, with chert, about	12
8.	First Clay-band	1
7.	Massive limestone, white to grey	70
6.	Second Clay-band	1 to 3
5.	Massive limestone, white to grey	46
4.	Third Clay-band	6 in. to 1
3.	Massive limestone, white to grey, blue near base, about	50
2.	Fourth Clay-band	6 in. to 1
1.	Massive limestone, light blue to grey, of which there are seen in the quarry	15

The Geological Survey memoir, *North Derbyshire*, 2nd ed., 1887, gives the thickness of bed No. 9 as 150 feet (p. 82), which is an obvious error.[1] The total thickness of the thin-bedded blue limestone, above the first clay-band, probably does not exceed 65 feet anywhere in the inlier. I have taken the thickness of bed No. 7 from the same memoir (p. 82), which entirely omits bed No. 8, although it is at least a foot thick in Cliff Quarry, but now much overgrown.

The first and second clay-bands are also exposed in Hilt's Quarry in the southern part of the inlier, and a clay-band, which is probably the first, is well seen in a quarry known as the 'Old Quarry', a short distance south-east of Hilt's Quarry.

[1] Cf. C. B. Wedd, Geol. Surv. Mem., Explanation of Sheet 125, 1908, p. 18.

The clays consist of stiff, plastic material, containing much moisture when first exposed, generally of a bluish-grey colour, and frequently with ochreous upper and lower surfaces, the variations in colour being apparently due to varying quantity of iron oxides. The central portion of the second clay, where exposed in Cliff Quarry,[1] is black and friable, but it does not show these features elsewhere. Minute cubes of pyrites are sporadically abundant throughout the clays.

With the exception of the first, which is generally covered by thin-bedded rock, all the clay-bands are intercalated between massive beds of limestone, without any gradation from limestone to clay, above or below.

After careful examination I have been unable to find any traces of organic life in these clays, with the exception of the black central portion of the second clay-band where exposed in Cliff Quarry.

The surface of the rock below the clay-bands is always found to be hummocky or mammillated, and not infrequently worn into deep furrows and holes, much resembling 'pot-holes', which are always filled with the clay.

Very similar clays, or 'way-boards' as they are called by miners, a term adopted by geological writers as far back as Whitehurst (1778), are frequently seen in other parts of the limestone of Derbyshire, and have been long recognized by their field relations to be decomposed toadstone. Thus, Farey (1811) says: "In many places it [toadstone] appears, both in deep Mines and at its basset, as a plastic Clay, often of a bluish grey colour, where the numerous Meers or Cattle-Ponds of this district occur upon its basset edge, . . ."[2]

Microscopic Structure.

A process of careful levigation and microscopic examination of their heavier constituents, after removal of the finer mud or 'clay-substance', show that these clays contain little or no quartz, but a fair amount of decomposing felspar, chloritic material, and sometimes abundant pyrites in minute cubes. Thin sections of material from all the exposures named above appear to bear out the same result. Owing to the mass of opaque matter it is not always easy to identify the minerals, but chloritic and felspathic material are seen, with perhaps a little secondary quartz. One of the sections, that of a specimen of the second clay-band from Hilt's Quarry, is especially interesting, in that it shows radiating aggregates giving a black cross in polarized light of a secondary mineral formed in the clay, which I have not been able to identify. It may perhaps be epidote.

Chemical Composition.

Below are given analyses of the clays and also, for purposes of comparison, of typical Derbyshire lavas decomposed to clay. The resemblance is striking, but by no means conclusive as to the origin

[1] Cf. H. H. Arnold-Bemrose, "A Sketch of the Geology of the Lower Carboniferous Rocks of Derbyshire": Proc. Geol. Assoc., vol. xvi, p. 177, 1899.

[2] *General View of the Agriculture and Minerals of Derbyshire*, vol. i, p. 278.

of the clays. It would be easy to quote analyses of true sediments bearing an equal resemblance to these in their main features. There is, however, one point worth noting. No carbon, either free or in the form of hydrocarbons, was found in any of the clays under discussion.

Summary and Conclusions.

The first and second of these clay-bands have been considered by recent geological writers to be of sedimentary origin, as will be seen from the following references. Of the third and fourth bands I have found no mention by any writer.

The Geological Survey memoir, *North Derbyshire*, 2nd ed., 1887, refers as follows (p. 82) to the second clay-band in Cliff Quarry and the underlying limestone: "The upper surface [of the underlying limestone] is very curiously water-worn into furrows and pot-holes, some of the latter being as much as two feet deep.[1] We have already noticed that the surface of the limestone beneath a toadstone bed is sometimes marked in the same way, and supposed it to have been done by water, charged with carbonic acid, trickling along between the beds.[2] The clay-band holds about the same position in the series as the toadstone at Ashover and the first toadstone at Matlock, but it has not in the least the look of a decomposed lava or ash."

It is difficult to understand the last statement, except as regards the central portion of the second clay where it is black and friable as above stated. Many of the clays, which are recognized as decomposed toadstone, in the limestone of Derbyshire are remarkably similar in the field to the clays under discussion.

Mr. C. B. Wedd, in the Geological Survey memoir, Explanation of Sheet 125, 1908, p. 18, states that "the white limestone [in the inlier] includes occasional bands of shale two feet thick or more"; which can only refer to these clay-bands. Again (p. 19), he describes the clay-band exposed in the Old Quarry as "a bed of ochreous marl about three feet thick", and (p. 20) the first clay-band, where seen in Hilt's Quarry, as "a bed of shaly marl of which the top is level".

I venture to think that the following features, described above, are difficult to reconcile with the sedimentary view:—

1. The abrupt transition from a clay, 2 or 3 feet in thickness, to massive limestone which was evidently laid down in deep and clear waters, both above and below the clay (except as regards the thin-bedded limestone above the first clay).

2. The absence of organisms (microscopic or otherwise) except in one special instance mentioned above.

3. The absence of original clastic quartz—an invariable and generally abundant constituent of true sedimentary clays—the waste of a land-surface.

4. The absence of carbon, either free or in the form of hydrocarbons, of which all sedimentary clays appear to possess a proportion, frequently a very minute one. This constituent is often held in

[1] 'Pot-holes,' up to 6 feet in depth, have recently been exposed below the clay-band in the Old Quarry.

[2] Cf. H. H. Arnold-Bemrose, op. cit., p. 204. Also "The Toadstones of Derbyshire": Q.J.G.S., vol. lxiii, p. 253, 1907.

solution, and is derived, as may be supposed, from the organic life of the waters which bore such clays to their resting-place.

5. The frequent local presence of minute cubes of pyrites. This mineral appears to be always of secondary origin in sedimentary clays, and is supposed to be due to the reducing action of decaying organic matter, sometimes through the agency of enzymes, on solutions of ferrous sulphate in the sea.[1] Here we have no organic matter to set up the reaction.

On the other hand, the great similarity in appearance of these clays, in the field, to clays resulting from the decomposition of toadstone, is suggestive of volcanic origin. The features named above, as lending no support to the sedimentary view, may perhaps be held to favour this suggestion.

The field relations with regard to the country rock, the absence of original clastic quartz and carbonaceous material, and the presence of pyrites are features which these beds share with other clays in the county which are recognized as decomposed toadstones.

It must be admitted that the microscopic structure does not give much positive evidence in favour of the volcanic view, but I have found nothing on any of the slides prepared from these clays to negative that view. In these thin beds, saturated with percolating carbonated waters, decomposition would probably proceed so far that most of the original minerals in the basalt or tuff from which they might be derived would be destroyed. It appears probable, however, that in the initial stages of the process, the ferro-magnesian constituent would be converted into the chloritic material seen on the slides, and silica would be liberated by the decomposition of the felspars, so that the presence of secondary quartz can be easily explained.

Further suggestive evidence may be mentioned.

The 'pot-holes' referred to above are, so far as I am aware, only found elsewhere below a toadstone bed, and there seems no reason why there should be an exception to this rule in the Crich area.

A bed of lava is known to exist in the limestone of Crich Hill "at depths varying from 180 to 480 feet",[2] and this again indicates that the area was well within the range of Carboniferous volcanic activity.

There remains a difficulty to be faced, viz. the presence of fossils in a part of one of the exposures already alluded to. Dr. Arnold-Bemrose describes the second clay-band, where exposed in Cliff Quarry, as "a bed of black shale containing a few fossils".[3] It has been mentioned above that the central portion of this bed is here black and friable, in which respect it differs from the other clays, and it undoubtedly contains a few fragmentary traces of fossils which are always, so far as my observation goes, so badly preserved as to be

[1] Cf. H. A. Miers, *Mineralogy*, 1902, p. 328; also G. A. J. Cole, *Rocks and their Origins*, 1912, pp. 84, 85.

[2] H. H. Arnold-Bemrose, "The Toadstones of Derbyshire": Q.J.G.S., vol. lxiii, p. 266, 1907.

[3] "A Sketch of the Geology of the Lower Carboniferous Rocks of Derbyshire": Proc. Geol. Assoc., vol. xvi, p. 177, 1899.

incapable of identification. The black colour is no doubt due to the presence of ferrous sulphide. Minute crystals of selenite are abundant, suggestive of the action of decomposing pyrites on carbonate of lime.

It is not easy to explain the presence of these fossils in this limited exposure, but their fragmentary condition and the entire absence of carbonaceous matter in the bed seem to indicate a derivative origin. One or two suggestions may perhaps be permitted. If this black central portion of the bed represents a local shower of ash, following a temporary cessation of the eruption of lava, the presence of fossils would present no difficulty. On the other hand, cases could be cited in which a rapidly cooling lava-flow has embedded remains without entirely destroying them, and it seems not impossible that this may have happened here.[1] Whatever the solution, the great difference between this portion of the bed and its other exposures, in structure, chemical composition, and appearance, would seem to indicate some difference in origin.

Another objection which may be raised against the hypothesis of volcanic origin is the absence of alteration in the rock below the clays. It must be borne in mind that such thin lava-flows would cool very rapidly on the sea-floor, and in other parts of the county very little and sometimes no alteration has been effected in the rock in contact with beds of basalt much thicker than these clays.[2]

Dr. Arnold-Bemrose has kindly called my attention to the fact that the view set forth in this paper is not of recent origin. Thus, sixty years ago Sir H. de la Beche wrote as follows: "Although there are clays amid the limestones in the relative positions of the igneous rocks, and some of these seem clearly little else than such rocks in a highly-decomposed state, retaining the arrangement of their component mineral substances, as, for example, *at the isolated boss of limestone at Crich* [italics mine], . . . it would scarcely be safe to conclude that all lying nearly in the same general geological levels were so, inasmuch as some of them may be clays of another character. Care on this head is rendered necessary by finding a clay—a true under-clay of the coal-measure kind—supporting a thin bed of impure coal in the higher part of the limestone series near Matlock Bath."[3]

It is an interesting circumstance that, in a quarry near Matlock Bath, there is at the present time a bed of clay exposed, supporting a thin bed of black shale with *Pterinopecten papyraceus*, and occasionally a thin coal is found on the clay. There can be little doubt that these are the beds referred to by Sir H. de la Beche. I have examined this clay, and although in external appearance it much resembles a fireclay, in microscopic structure it is quite different and agrees very closely with the clays described above. I have little doubt that it is of igneous origin. The rock above is thin-bedded, with thin partings of unmistakable detrital structure between the beds, so that no doubt a shore-line was not far distant, and thus the presence of the shale and coal is not so anomalous as it otherwise would be.

[1] Cf. Lyell, *Principles of Geology*, 12th ed., vol. ii, p. 516, 1875.
[2] Cf. Geol. Surv. Mem., *North Derbyshire*, 2nd ed., 1887, p. 20.
[3] *Geological Observer*, 2nd ed., 1853, p. 560.

Nine years earlier than the date of the above quotation from De la Beche, John Alsop makes the following significant statement:[1] "In a section of Crick [Crich] cliff, what is at one shaft a thin bed of clay a foot thick, becomes within a short distance fourteen feet thick, *and contains large nodules of compact toadstone* [italics mine], . . ."

I have also been informed that the late A. H. Stokes, F.G.S., H.M. Inspector of Mines, held the opinion that the clays above described were of igneous origin.

If, then, these clays represent lava-flows, or possibly in some cases tuffs, the interesting question follows, where was the vent situated from which they were erupted? With the Editor's permission I propose to discuss this question in a subsequent paper.

ANALYSES BY MR. ERIC SINKINSON.

	First Clay-band (blue central portion), Hilt's Quarry.	First Clay-band (ochreous margin), Hilt's Quarry.	Second Clay-band, Hilt's Quarry.	Second Clay-band (black central portion), Cliff Quarry.	Third Clay-band, Cliff Quarry.	Fourth Clay-band, Cliff Quarry.	Lower Lava of Matlock Area (Clay), Hoptonwood Quarry, near Wirksworth.	Upper Lava of Matlock Area (Clay), Salter's Lane, Matlock.
SiO_2 . . .	46·66	48·60	47·50	58·46	56·61	51·04	47·83	47·11
Al_2O_3 . . .	24·76	24·23	29·62	22·34	31·98	31·63	22·74	25·99
Fe_2O_3 and Fe O	8·82	21·99	4·48	—	0·47	0·30	4·76	9·87
$Fe S_2$ . . .	—	—	—	1·19	—	—	5·02	—
Fe S . . .	—	—	—	1·02	—	—	—	—
Mg O . . .	2·72	trace	1·35	1·46	1·02	1·22	2·50	3·23
Ca O . . .	1·97	0·42	0·96	0·56	1·07	1·20	1·19	1·95
Na_2O and K_2O	2·02	0·71	3·00	2·00	2·82	2·95	3·30	4·93
H_2O . . .	12·52	3·72	12·73	12·97	6·03	11·66	12·66	6·92
CO_2 . . .	0·53	0·33	0·36	—	—	—	—	—
	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00

V.—Outlines of the Geology of Mozambique.

By Arthur Holmes, B.Sc., A.R.C.S., F.G.S., and D. A. Wray, B.Sc., F.G.S.

In 1911 Mr. E. J. Wayland, F.G.S., and the authors visited the Portuguese East African province of Mozambique in the interests of the Memba Minerals, Ltd. The country was very little known geographically, and except along the coast, it was a *terra incognita* to geologists. We hope in due course to publish a detailed account of our observations, but as it will be some time before this can be completed, it seems advisable to give a short résumé of the salient geological features of the territory. It is hoped that these results

[1] Brit. Assoc. Report, 1844, Trans. Sections, p. 52.

will prove of interest to students of East African geology, especially in their bearing on problems of theoretical interest concerning the geological history of that portion of the globe.

With the exception of a narrow coastal strip consisting of Cretaceous and Tertiary sediments with some volcanic rocks, the whole country consists of a complex of gneisses and other foliated rocks intruded upon by massive igneous rocks and their attendant dykes. Although we proceeded as far inland as latitude 37° E., no further signs of any sedimentary rocks were met with. Rocks probably of Karroo age occur immediately to the north in the Lujenda Valley, to the east in British Central Africa, and to the south in Zambesia, but in each case they owe their preservation to trough-faulting. Denudation appears to have entirely removed such formations from the surface of Mozambique. The oldest sediments lying on the metamorphic rocks are of Lower Cretaceous age, and consequently there is little direct geological evidence for the age of the complex. However, judging from their lithological features, the intricacy of their structure, and their similarity to corresponding fundamental rocks in other parts of the globe, we feel justified in assigning these rocks to the Archæan. Particularly striking is their resemblance to the rocks of British Central Africa, British and German East Africa, and Madagascar; for this consists in not only their detailed field characteristics and the peculiar 'inselberge' landscape they give rise to, but also in their mineral and chemical characters.

The country inland from Mozambique gradually changes in type. After the low-lying sedimentary zone is crossed the surface is that of a gently rising plateau from which many isolated peaks and hills arise. They produce a peculiar type of topography which also occurs in German East Africa, where it has been examined and its origin discussed by Bornhardt.[1] In Northern Nigeria[2] the scenery is very similar, and this type appears to be a marked characteristic of the gneiss and granite regions of Africa. Fantastic peaks, rocky domes, and cone-shaped hills rise precipitously from the plateau, like islands surrounded by a verdant sea of forest. By their aggregation lofty mountain blocks and ranges are formed, and one of the most extensive of these in Mozambique is the Chica range, which stretches for 20 miles in a N.N.E. and S.S.W. direction, about 150 miles from the coast. Further west are the great massifs of Ribaue and Inago, rising to 5,000 and 6,000 feet respectively, whilst in the western limit of the country rise the famous Namuli Peaks, so long conjectured to be of volcanic origin, but consisting of a huge block of granite and gneiss with conical peaks, and rising to 8,000 feet above sea-level. These four mountain groups define the watershed of the territory, and from them the rivers flow north, south, and east.

In the metamorphic series of Mozambique there are but few representatives of true schists. From the north-east of the territory,

[1] W. Bornhardt, *Die Oberflächengestaltung und Geologie Deutsch-Ost-Afrika*, Bd. vii, Berlin, 1900; see especially pp. 34–9.

[2] J. D. Falconer, *Geology and Geography of Northern Nigeria*, London, 1911; see especially plates v. vii, and xvii.

approaching the mouth of the Lurio or Luli River, chlorite- and mica-schists are recorded, with thin bands of hæmatite- and graphite-schists. They appear to be isolated remnants of a formation now mostly removed by denudation. Dr. Voit has remarked that a schistose series is preserved more typically in the south of the continent, while towards the Equator gneisses are found to be more important. In each case the metamorphic rocks are accompanied by intrusive granites. Our investigations fully bear out Dr. Voit's observations.[1]

The dominant rock of the country is a grey biotite gneiss, often containing hornblende, which varies from coarsely banded varieties to finely foliated types. The former contain granular bands of quartz and felspar, and it is often impossible to distinguish them from pegmatite intrusions. With the development of patches of felspar in place of bands the rock passes into an augen-gneiss, and this in turn may sometimes be traced into a slightly porphyritic granite, with little sign of any directive structure. The fine-grained type on the other hand merges into mica-schist, though it is but rarely that the latter is found. Associated with these rocks are lenticular masses of hornblende-gneiss and, to a less extent, of garnet and epidote-bearing rocks. Quartzites and crystalline limestones are nowhere common in this territory, but several bands intercalated with the gneiss have been noted, sometimes of considerable thickness. The gneisses are the oldest rocks of the country, and into them granite intrusions have penetrated at two distinct periods, and perhaps also at others. The granite rises in great domes, often with steep sides, and from them the overlying gneiss dips away in every direction. By exfoliation thin flakes of gneiss are split off parallel to the foliation planes, and in this way the hills tend to retain the outline of the granite core, a favourable condition for the production of the 'inselberge' landscape. The granites are notably poor in ferromagnesian minerals, and present a contrast to the gneisses with their much higher proportion of biotite and hornblende. Otherwise the mineralogical constituents are very similar in the two cases. Felspar is the most abundant mineral, microcline[2] being constantly present, as is characteristic of all the old granites of Central and South Africa. Associated with the granites are enormous numbers of pegmatite dykes, sometimes as much as 10 feet across, but more usually not as many inches. Iron-ores are very commonly present, hæmatite and magnetite being everywhere very plentiful. Basic dykes also enter into the architecture of the complex, but they are sparingly distributed, and of their genetic relations and age nothing is yet known.

The coastal strip of Cretaceous rocks has an average width of 10 to 12 miles, but the strata do not form a continuous outcrop, and at Memba Bay the coarse Archæan gneisses reach the sea in rugged sea-cliffs fringed with recent coral-reefs. The Cretaceous beds have a very gentle dip towards the south-east, and seem to have been subjected to little movement since their deposition. Three main

[1] F. W. Voit, Trans. Geol. Soc. South Africa, vol. x, p. 92, 1907.
[2] C. B. Horwood & A. Wadé, GEOL. MAG., Dec. V, Vol. VI, p. 459, 1909.

groups or series are provisionally recognized. In descending order they are:—

3. Conducia Beds.
2. Mount Meza Beds.
1. Fernão Vellozo Beds.

Of these beds only the Conducia Beds[1] have been hitherto noticed.

The Fernão Vellozo Beds are admirably exposed in many coast and inland sections from Memba southwards to the district around Fernão Vellozo or Masasima harbour. A little south of the harbour, near Chief M'shilipo's kraal, they consist of an alternating series of limestones and shales, and in these we fortunately obtained a small assemblage of fossils which show distinct Uitenhagian characters, and conclusively determine the beds in question to be of Neocomian age.

The second series, the Mount Meza Beds, consist predominantly of sandstones with some calcareous bands. They form several flat-topped hills in the neighbourhood of the coast, Mount Meza itself being over 1,000 feet above sea-level. Judging by the fact that they conformably succeed the Fernão Vellozo Beds, and also underlie the Conducia Beds, they are in all probability of Aptian and Albian age. An Aptian fauna along this coast has already been described by Professor Kilian[2] from so near a locality as Delagoa Bay.

The highest Cretaceous Series (3), the Conducia Beds, are well exposed in Conducia Bay, a few miles north-west of Mozambique Island, and a description of their fauna has been contributed by Choffat[3] to the Portuguese Geological Commission. Choffat referred these beds to the Upper Cretaceous, ranging from Vraconian to Senonian, and he pointed out their close affinities with the Southern Indian development (Ariyalur and Utatur stages).

The discovery of these Cretaceous deposits along the Mozambique coast, and exactly opposite the Island of Madagascar, shows that probably the Indo-African land connexion had already been broken in early Cretaceous times.[4]

Above the Cretaceous, and resting with a slight unconformity on them, comes a series of beds referred by Sadebeck[5] to the Upper Eocene or Oligocene. They have yielded some corals and Foraminifera. They occur in two facies; one a poorly consolidated limestone, and the other a hard sandstone frequently conglomeratic. The limestones on Mozambique Island weather in a peculiar manner, giving rise to deep solution pits circular in outline.

[1] P. Choffat, "Contributions à la connaissance géologique des colonies Portugaises de l'Afrique: Le Crétacique de Conducia": Comm. Serv. Géol. Portugal, Lisboa, 1903.

[2] Kilian, "Sur la présence de l'étage Aptien dans le sud-est de l'Afrique": Compt. Rendus, cxxxv, No. 1, pp. 68–71, 1902, and Bull. Soc. Géol. France, ser. iv, ii, p. 358, 1902.

[3] P. Choffat, "Contributions à la connaissance géologique des colonies Portugaises de l'Afrique: Le Crétacique de Conducia": Comm. Serv. Géol. Portugal, Lisboa, 1903.

[4] For further discussion of this problem see especially F. L. Kitchin, "Invertebrate Fauna of the Uitenhage Series," Annals South African Museum, vol. vii, pt. ii, pp. 51–6, 1908.

[5] A. Sadebeck, "Geologie von Ost-Afrika" in Von der Decken's *Reisen in Ost-Afrika*, Leipzig, 1879.

Of great interest are the lavas so well developed along the coastal strip and hitherto not described or referred to elsewhere. Basaltic lavas were extruded over a large area, but denudation has now reduced them to scattered remnants.

Amygdaloidal basalts, clearly the result of fissure-eruptions, are found in a zone never far from the coast, and stretching northwards from Mokambo Bay for some 20 miles. Associated with them, and representing the ducts up which the molten magma found its way to the surface, are numerous dykes and sills of dolerite. Pebbles of agate and jasper, derived from the cavities in the basalt, are found far to the west and north of the present exposures, and indicate roughly the former extensions of the flows. Besides quartz and chalcedony, zeolites of various types are found filling the amygdules. The basalt and dolerite differ only in the coarser crystallization of the latter and its relative freedom from vesicles. Olivine appears to be entirely absent, its place being taken by the orthorhombic pyroxenes. In this respect the rocks differ from other East African basalts, for in the latter olivine is generally a noteworthy constituent. The flows lie indiscriminately on the Archæan gneisses, and on the Cretaceous and Tertiary sediments, while the dykes and sills intrude through the same formations. Where they are in contact with the Cretaceous limestone, this has been transformed into a crystalline aggregate within a few inches of the contact.

Along the coast and for some distance inland are found numerous raised beaches lying at heights up to 25 feet, while the whole coast is fringed with coral reefs. These deposits afford further proof of the recent uplift of the East African coast, evidences of which have also been met with both to the south and north. Another indication is found in the rejuvenation of the streams which, thus endowed with greater energy, have been enabled to cut gullies in the gravels and sands of an earlier epoch. The superficial deposits which are now being dissected are the products of disintegration of the older rocks. These we found to consist in general of two types: the first, enveloping the hills, and due in the main to the disintegration of rock in situ, and the second found in the plains and clearly showing evidence of having been transported by water-action.

The decomposition of rocks in situ gives rise to two widely different varieties of residual deposits. The one consists of kaolin, the other of laterite, and in most cases angular particles of quartz are present. The former type of alteration calls for little comment, but it may be observed that the gradual transition of hard rock into soft china-clay could easily be traced in the field, suggesting that surface action alone had brought about the change.

A quartzose laterite is the more usual superficial formation. In general it forms hard, brown, slaggy-looking masses, with concretions of iron-ore containing numerous angular fragments of quartz. The rock is penetrated by cavities which may be partly occupied by a powdery ferruginous earth. The laterites usually occur in bands running parallel to the strike of the gneiss, and often these lie near the crest of low ridges which follow the same direction. They also occur near the sides of small watercourses, of which the majority

dry up during several months of the year. In the beds of these streams concretions of limonite appear to be forming at the present time. Similar concretions are found in the alluvial sands, and in many places a ferruginous cement has hardened the upper layers of the latter. These phenomena are probably due to the evaporation of iron-bearing solutions brought near the surface, with consequent deposition of the hydrated oxides. The origin of laterites is a much-discussed problem, but we believe that many of the Mozambique varieties have originated in this way, a view in support of which we hope to present fuller evidence on a future occasion.

VI.—The Carboniferous Succession in the Forest of Dean Coalfield.

By T. Franklin Sibly, D.Sc., F.G.S., Lecturer on Geology in King's College, London.

A. Introduction.
B. The Lower Carboniferous Rocks.
C. The Intra-Carboniferous Unconformity.

A. Introduction.

The following preliminary account is presented as the result of several weeks of field-work on the northern and eastern margins of the Forest of Dean Coalfield, carried out partly in 1910 and partly in the present year. The area which I have examined lies almost wholly within Sheet 43 S.E. of the 1 inch Geological Survey Map (Old Series), but extends a short distance into Sheet 43 S.W. In portions of this area, the Lower Carboniferous rocks have been studied in detail and mapped. The Coal Measures, however, have as yet been examined only in their relation to the Lower Carboniferous strata. The present communication is, therefore, confined to a demonstration of the important unconformity which exists between the Coal Measures and the Lower Carboniferous rocks, together with a brief description of the latter. I am continuing my investigations, and I hope to give at some future date a more comprehensive account of the geology of the coalfield. In the meantime, the following outline may be of interest.

The Carboniferous succession in the north and east of the coalfield comprises the following members:—

Lower Carboniferous.

1. *Carboniferous Limestone Series.* The strata of this division succeed the Old Red Sandstone with perfect conformity, and are themselves overlain conformably by

2. *The Drybrook Sandstone.* A thick sandstone formation, the 'Millstone Grit' of previous writers.

Upper Carboniferous.

3. *Coal Measures.* As will be shown, the strata of this series lie unconformably, and in some places with great discordance of dip, upon the Lower Carboniferous rocks (2) and (1).

B. The Lower Carboniferous Rocks.

Carboniferous Limestone Series.

Mr. E. Wethered has given some description of the strata of this series in three papers.[1] More recently Dr. A. Vaughan has given[2] an outline of the sequence in the Mitcheldean district, on the north-eastern margin of the coalfield, and a correlation of this sequence with the Avonian of the Bristol area. My own studies confirm Dr. Vaughan's conclusion that the top of the Carboniferous Limestone Series in the Forest of Dean lies far below the summit of the Avonian; but the features of the series as I have observed them differ in several important particulars from those outlined by him.

The Carboniferous Limestone Series is readily capable of a three-fold subdivision on lithological grounds. The following table gives the approximate thickness of each subdivision in the Mitcheldean district, and a correlation with the zones of the Avonian.

	Avonian Zones.
(c) *Whitehead Limestone*, 20 to 50 feet.	C
(b) *Main Limestone*, about 320 feet	Z
(a) *Lower Limestone Shales*, about 180 feet . .	K

Lower Limestone Shales. This subdivision represents the *Cleistopora*-zone (K), and probably includes the base of the *Zaphrentis*-zone (Z) also. It comprises limestones and shales of very varied character, and passes down conformably into the sandstones which form the top of the Old Red Sandstone. Its lowest member is a thick band of limestone, often oolitic and gritty. At the junction with the Old Red Sandstone an alternation of limestone with sandstone occurs throughout a small thickness of beds, but there is no appreciable development of a transition-series comparable, either faunally or lithologically, with the *Modiola*-phase at the base of the Avonian in the Avon section. The subzones K_1 and K_2 can be distinguished, but in each sub-zone the faunal assemblage presents considerable differences to the corresponding assemblage in the Bristol and Mendip areas.

An important feature of the *Cleistopora*-zone in this area is the strong development of *Modiola*-phase (calcareous lagoon-phase) deposits in the middle and upper portions of the zone. These deposits are of exceedingly varied lithological character. As regards

[1] "On the Lower Carboniferous Rocks of the Forest of Dean, as represented in Typical Sections at Drybrook": Q.J.G.S., vol. xxxix, p. 211, 1883. "On the Structure and Organisms of the Lower Limestone Shales, Carboniferous Limestone, and Upper Limestones of the Forest of Dean": Geol. Mag., Dec. III, Vol. III, p. 530, 1886. "On the Lower Divisions of the Carboniferous Rocks in the Forest of Dean": Proc. Geol. Assoc., vol. x, p. 510, 1887–8.

[2] Q.J.G.S., vol. lxi, pp. 251–2, 1905.

palæontological characters, they present the usual abundance of ostracods and occurrence of modioliform lamellibranchs; but their most striking feature is the abundance of *Serpula*-like annelids, or *Mitcheldeania*-like algæ, or both these fossils, in certain bands of calcite-mudstone. The *Serpulæ* often occur in the form of large, fasciculate masses of tubes, but exhibit a variety of forms.

Main Limestone. This is composed in bulk of dolomites and dolomitic limestones, with a local and variable development, in the upper part, of crinoidal or oolitic limestones which have escaped dolomitization.

The lower, and major, portion belongs to the *Zaphrentis*-zone, and consists for the most part of finely crystalline dolomites, red, yellow, or grey in colour. Fossils are so scarce in these beds that the sub-zones Z_1 and Z_2 have not yet been distinguished.

The upper part is of *Syringothyris* age (C), and belongs mainly, at least, to the sub-zone C_1. Essentially, this upper portion of the Main Limestone consists of a series of crinoidal limestones capped by a few beds of coarsely crystalline dolomite. The crystalline dolomites, which immediately underlie the Whitehead Limestone, are persistent, and the lower beds of the crinoidal limestone-series are always dolomitic; but the intervening beds vary considerably in character, both from bed to bed in vertical sequence, and also when traced laterally. The variations in these intervening beds are chiefly due to (*a*) the very variable extent to which dolomitization has affected the rocks, and (*b*) the sporadic development of oolitic structure. In some localities all the beds are more or less strongly dolomitized. Elsewhere the dolomitization is distributed irregularly, so that beds of large collective thickness have locally escaped dolomitization. Important deposits of hæmatite occur in this series of limestones; and the maximum amount of dolomitization of the rocks is found in those localities where the hæmatite-deposits are well developed. On the evidence collected up to the present, it appears that in this whole series of crinoidal limestones a certain amount of 'contemporaneous' dolomitization, almost confined to the lower beds, has been followed by extensive but irregularly distributed 'vein-dolomitization' connected with the formation of the hæmatite-deposits.

Whitehead Limestone. This small subdivision is of special interest and importance, inasmuch as it constitutes a well-marked *Modiola*-phase. The rocks composing it are chiefly limestones, with subordinate calcareous clays which often contain numerous limestone-nodules. Locally, some of the beds are dolomitized. The limestones are very variable in character, but among them finely oolitic rocks and calcite-mudstones of chinastone type predominate. *Mitcheldeania*-nodules and (?) *Girvanella*-nodules are common in many of the limestones, and sometimes so abundant as to form the bulk of the rock. A certain amount of fine quartz-sand occurs in all the beds; and the occasional intercalation of bands of calcareous grit foreshadows the oncoming of the Drybrook Sandstone, into which formation the Whitehead Limestone passes up conformably.

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B. The Lower Carboniferous Rocks.

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I have discovered no fossil evidence to support Dr. Vaughan's

correlation of the Whitehead Limestone with the Upper *Seminula*-zone.[1] Indeed, I have as yet found no determinable corals or brachiopods in this subdivision; and at present I would only point out that, on the evidence of the underlying beds, the Whitehead Limestone represents some horizon not far removed from the summit of the *Syringothyris*-zone. The study of the south-western margin of the coalfield will probably throw light upon this question; for in proceeding south-westward from Mitcheldean we approach the Chepstow area, in which the *Seminula*-zone is finely developed.[2]

Drybrook Sandstone.

This formation has yet to be studied in detail. It is composed very largely of pure quartz-sandstones, often coarse-grained and friable. Conspicuous bands of quartz-conglomerate occur; some clays and shales are intercalated with the sandstones; and some hæmatite deposits are developed. The thickness of the beds at their outcrop in the neighbourhood of Ruspidge, south of Cinderford, is at least 600 feet.

Mr. Wethered has recorded[3] a *Lepidodendron* "allied to *L. griffithii*, Brongn." from the lower beds of this formation at Drybrook. No other determinable fossils have yet been recorded.

The Lower Carboniferous age of the 'Millstone Grit' in the Mitcheldean district was demonstrated by Dr. Vaughan[4] in 1905. The term Drybrook Sandstone—from Drybrook, near Mitcheldean, Gloucestershire—is now proposed instead of 'Millstone Grit'. We have seen that the base of the Drybrook Sandstone lies conformably upon limestones whose horizon cannot be far removed from the top of the *Syringothyris*-zone, and we may conclude that the whole of this formation is older than the Millstone Grit proper.

C. The Intra-Carboniferous Unconformity.

Mr. E. A. Newell Arber has proved conclusively that the Coal Measures of the Forest of Dean belong mainly, if not wholly, to the Upper Coal Measures.[5] I find that *the relation of the Coal Measures to both the Carboniferous Limestone and the Drybrook Sandstone is one of pronounced unconformity.*

On the eastern margin of the coalfield, the strata of the Carboniferous Limestone and Drybrook Sandstone dip steeply westward, and consequently their outcrop forms only a narrow band. Between Mitcheldean on the north and Ruspidge on the south, that is, throughout a distance of about 4½ miles, the superincumbent Coal Measures, which dip westward at a small angle, rest upon the Drybrook Sandstone. South of Ruspidge, however, the Coal Measures overstep eastward into the Carboniferous Limestone and conceal the Drybrook Sandstone. The transgression is gradual at first, but near Howbeach Colliery, about 2 miles south of

[1] Q.J.G.S., vol. lxi, p. 252, 1905. [2] A. Vaughan, ibid., p. 251.
[3] Q.J.G.S., vol. xxxix, p. 215, 1883. [4] Q.J.G.S., vol. lxi, p. 252, 1905.
[5] E. A. Newell Arber, "On the Fossil Flora of the Forest of Dean Coalfield (Gloucestershire), and the Relationships of the Coalfields of the West of England and South Wales": Phil. Trans. Roy. Soc., vol. ccii, B, pp. 233–81, 1912.

Ruspidge, the base of the Coal Measures passes rapidly eastward across the remainder of the Carboniferous Limestone Series, on to the Old Red Sandstone. The Carboniferous Limestone remains concealed by Coal Measures for a distance of some 3 miles south of Howbeach Colliery; it reappears near Lydney, at the southern end of the coalfield.

Close to Howbeach Colliery, in the gorge of Blackpool Brook, an old quarry shows the unconformable junction of Coal Measures and Carboniferous Limestone. The quarry-face shows dolomites belonging to the Main Limestone, dipping north-westward at about 60°, overlain by Coal Measure sandstones which dip westward at a small angle.

On the northern margin of the coalfield, west and north-west of Drybrook, the beds of the Carboniferous Limestone Series, being gently inclined, cover a large area. Not far west of Drybrook, the Drybrook Sandstone is overstepped by the Coal Measures. Farther west, beyond Ruardean, the Coal Measures rest upon the Main Limestone; while to the north of Ruardean, across the valley, a large outlier of Coal Measures reposes directly upon the Lower Limestone Shales at Howle Hill.

Some of the features just described have been noticed by earlier writers. In particular, the interruption of the Limestone-outcrop on the south-eastern border of the coalfield, between Howbeach Colliery and Lydney, was noticed by Buckland and Conybeare,[1] who attributed it to a fault; and the same phenomenon was discussed and very clearly illustrated by Maclauchlan.[2]

H. D. Hoskold, writing in 1892, stated that near Howbeach Colliery "the Pennant rocks belonging to the Lower Coal Measures rest immediately upon and are in contact with the Carboniferous Limestone".[3]

Quite recently Mr. Newell Arber, in his important paper[4] on the fossil flora of the coalfield, has discussed the relation of the Coal Measures to the underlying strata at some length. He writes as follows:—

"Reviewing the present evidence I am inclined to think that it will eventually prove that an unconformity exists a short distance below the Lower Trenchard Coal perhaps a little above the Sandstone vein of Iron Ore. In this case the greater portion of the Millstone Grits, so-called, will be found to be simply a sandy facies of the Carboniferous Limestone Series, just as the lower beds have already been shown to be by Dr. Vaughan. I imagine that, in the Forest of Dean, the Upper Coal Measures rest unconformably on an ancient floor consisting for the most part of the higher sandy beds of the Carboniferous Limestone Series, though, in some parts of the area, on Carboniferous Limestone of normal facies or even on Old Red Sandstone . . . Owing to the general absence of sections, the unconformity has not, however, been demonstrated in the field. True Millstone Grits, Lower, Middle, and Transition Coal Measures

[1] Trans. Geol. Soc., ser. II, vol. i, p. 286, 1824.
[2] Trans. Geol. Soc., ser. II, vol. v, pp. 204–6, 1837.
[3] Proc. Cotteswold Nat. F.C., vol. x, p. 135, 1892.
[4] See n. 5, p. 420.

appear to be absent in the Forest of Dean, so that the unconformity in question is of considerable importance." [1]

The unconformity between the Coal Measures and the Lower Carboniferous rocks in the Forest of Dean represents a great gap in the Carboniferous succession. The break appears to be quite as extensive as that which Mr. E. E. L. Dixon has shown to exist in the Titterstone Clee Hills,[2] and it is doubtless due to the same earth-movement. The tectonic relations of the strata in both the Forest of Dean and the Titterstone Clee Hills, show clearly that a powerful earth-movement occurred at some date between Avonian and Upper Coal Measure times.

It would be premature to attempt any discussion of the bearing of this evidence upon the general tectonic history of Carboniferous times. But in this connexion it is important to note that future research in the Bristol and Somerset Coalfields may enable us to fix accurately the date of the earth-movement in question. A feature which may prove to be of great significance is the relation of the Pennant Grit to the Carboniferous Limestone in the Clevedon and Clapton district, near Bristol. In 1905, Dr. Vaughan expressed the opinion [3] that a considerable unconformity between the Coal Measures and the Carboniferous Limestone afforded the only possible explanation of the structure of that district.

REVIEWS.

Prehistoric Remains in Cornwall.

I.—Harlyn Bay and the Discoveries of its Prehistoric Remains. By the Rev. R. Ashington Bullen, F.L.S., F.G.S. Third edition. pp. 173. Harlyn Bay: Colonel Bellers, 1912. Price 1*s.* net.

HARLYN Bay lies to the east of Trevose Head in Cornwall, the western horn of the bay being formed by the comparatively hard greenstone (proterobase) of Cataclews Point, and the eastern side by Upper Devonian Slates. The southern and south-western portions of the bay are bordered by Blown Sand, which extends to Constantine Bay, thus isolating the headland of Trevose. As remarked by Mr. Clement Reid, "At Constantine the sand drifts right across the isthmus into Harlyn Bay, where it has overwhelmed an ancient British cemetery . . . The graves at Harlyn are partly dug in blown sand, but they have been overwhelmed by a much thicker sheet of similar material." [4]

We commence with a reference to the recent Geological Survey publications, as the attention of Mr. Bullen has evidently not been drawn to them. The first edition of his work was issued in 1901,

[1] E. A. Newell Arber, "On the Fossil Flora of the Forest of Dean Coalfield (Gloucestershire), and the Relationships of the Coalfields of the West of England and South Wales": Phil. Trans. Roy. Soc., vol. ccii, B, pp. 270, 277, 1912.

[2] Geol. Mag., Dec. V, Vol. VII, p. 458, 1910.

[3] Q.J.G.S., vol. lxi, p. 228, 1905.

[4] "Geology of the Country around Padstow and Camelford," 1910, p. 89, and Geological Survey Map, No. 335, 1910.

the second in 1902, and in the present volume he states that he incorporates the later discoveries made up to 1905, since which but little has been done.

The general section of the Harlyn Bay deposits is given by Mr. Bullen as follows:—

Blown shell-sand	12–15 feet.
Dark sand with slate implements, etc. . .	6 inches.
Cists with interments	2–4 feet.
Rubble and clay	1 foot.

The author refers to the Neolithic implements fashioned from shells of limpet and mussel, and from slate and flint. The occurrence of flint is interesting, but the material is found elsewhere in Cornwall, and in Mr. Reid's opinion seems to have been derived from some old Tertiary deposit now beneath the sea (op. cit., p. 93).

Figures are given of the human remains found in the cists, with notes on their characters by the late Dr. Beddoe and Professor Haddon. Other vertebrate remains found in Neolithic deposits include ox (*Bos taurus* and ? *B. longifrons*), sheep, pig, horse, rabbit, and goose, identified by Mr. E. T. Newton. The marine and non-marine mollusca are also noted, and among the latter *Helix aspersa* was obtained from a kitchen-midden, and *Hygromia montivaga* (West.) from under the grave-level at Harlyn. This being a Lusitanian shell and an entirely new record for England, the author takes the opportunity of discussing the question of migration and distribution of some of the mollusca. The work is of considerable interest to geologists in connexion with the early or pre-Roman portion of the Holocene period; but we have not referred here to many objects of archæological interest, of Neolithic, Roman, and later dates, which have been brought to light by the painstaking researches of Mr. Bullen[1] and of those associated with him. A useful index completes the volume.

II.—The Geology of the South Wales Coal-field. Pt. iii: The Country around Cardiff. By Aubrey Strahan, M.A., Sc.D., F.R.S., and T. C. Cantrill, B.Sc. Second edition. 8vo; pp. viii, 157, with 13 text-illustrations. 1912. Price 2*s*.

IN this new edition the memoir has been increased by ten pages and the price has been reduced by threepence. Sundry additions and corrections have been made. The useful tabular lists of the Silurian fossils from Cardiff and Usk have been omitted, perhaps on account of the ever-increasing perplexities in nomenclature; but the local lists of species are given. In the Old Red Sandstone the former 'middle series of dull-red grits and sandstones' is now termed Brownstones, and placed at the base of the Upper Old Red Sandstone; the Lower division comprises red marls with sandstones, cornstones, etc. References are made to the palæontological zones in the Carboniferous Limestone, but little work has been done in the Cardiff area, the new information relating mainly to the zonal work of

[1] [As we go to press the sad news reaches us of the sudden death of our dear friend Mr. Bullen, on August 14, when on his way to Germany.—H. W.]

Dr. T. F. Sibly in a small part of Somerset (at Worle Hill and Middle Hope) that is included in the Cardiff map. Further particulars are also given of the volcanic rocks of Somerset, of the Keuper and Rhætic beds, the Lias, and superficial deposits. Records of new well-borings are added, and the geological bibliography of South Wales and Monmouthshire has been brought up to date.

III.—The British Carboniferous Trepostomata. By G. W. Lee, D.Sc. Being vol. i, pt. iii of Memoirs of the Geological Survey of Great Britain. Palæontology, pp. 135–95 and pls. xiv–xvi. 4to. 1912. Price 3*s*.

THE Trepostomata, which form a sub-order of the Bryozoa, are abundant in Palæozoic rocks of different regions, but in their study there is "absolute need of thin sections and careful microscopical examination". Dr. Lee now distinguishes twenty-three species, of which twenty are new and three previously described. These are referred to already known genera; while one species is constituted the type of a new genus under the name *Koninckopora inflata* (de Koninck), a form referred to *Calamopora* by de Koninck, and to *Stenopora* by M'Coy. The species occur in the Lower Carboniferous rocks, and have been obtained from sundry localities in the west and north of England, Scotland, South Wales, the Isle of Man, and Ireland.

Egyptian Echinoids.

IV.—Notes sur les Échinides fossiles de l'Égypte. Par M. R. Fourtau. Bull. Inst. Égyptien, sér. v, tome v, pp. 137–76, pls. i–iv. 8vo.

OUR knowledge of the Echinoid fauna of the Upper Cretaceous is derived to a surprising degree from the discoveries that have been made in the Mediterranean region. Numerically, Echinoids are sufficiently abundant in the Chalk of Northern Europe, but their differentiation into genera and species is proportionately small when contrasted with the wealth of variety among those found in the belt of country between Algieria and Persia. Although the researches of Pomel and Cotteau, Perou and Gauthier for Algieria, of the last-named for Tunis and Persia, and of Fourtau for Egypt, are both admirable and bulky, they represent the results of but few and spasmodic expeditions when compared with the prolonged and persistent investigations that have been undertaken in Europe.

The maximum of specific differentiation in the Mediterranean Upper Cretaceous seems to have been attained by three groups of Echinoids. For the Regularia, *Cyphosoma* and its allies show the greatest variety; for the Holectypoida, *Coenholectypus*; and for the Spatangoida, *Hemiaster*. In the case of the last-named genus there have already been described a bewildering number of species, and hardly any paper dealing with the Echinoids of the region appears without some addition being made to the list.

The memoir under consideration is in some respects an aftermath of the recent paper by Dr. W. F. Hume on Secular Oscillation in Egypt (Quart. Journ. Geol. Soc., 1911), the specimens described having been largely used for the stratigraphical arguments in that work. The Cretaceous forms come from the extreme west of Egypt, partly from the borders of the Red Sea, and the Tertiary specimens from the Valley of the Nile. The latter are all derived from the Eocene Rocks, and are all Spatangoids, including one new species and one new variety. The Cretaceous species are more numerous, and give occasion for several systematic discussions of importance.

It is perhaps a sign of the times that in a systematic paper of this magnitude no new species of *Cidaris* are proposed, and it is certainly a relief for the student of the Cidaroida. A large number of Cyphosomatids, such as *Cyphosoma*, *Rachiosoma*, and *Psilosoma*, are described and figured, many being new. The last-named genus, founded by Pomel, is resuscitated after its recent rejection by M. Lambert, and its revival is supported by five pages of discussion and the description of a new species. It is lamentable to think of the amount of space and energy that have been expended over the unhappy indefiniteness of Pomel's generic diagnosis. It remains to be seen in what way the *Revue critique de Paléozoologie* will deal with this latest outbreak of heterodoxy, and M. Fourtau seems to anticipate severe treatment.

A considerable space is devoted to the *Holectypi*, and a new species, *H. dowsoni*, is described. The North African variety of *H. cenomanensis* receives a name, and is well figured. A new and very fragmentary form of *Archiacia* is described. Although the principle of the foundation of new species on imperfect specimens is usually disastrous, the excessive rarity of complete examples of this genus makes such treatment necessary, if any progress is to be made. A new *Echinobrissus*, and a form referred to *Epiaster* in default of a better resting-place, bring the list to a close, save for the *Hemiasters*. Three species of these are new, and the description of one, *H. toxasteristoma*, is accompanied by a valuable table of measurements.

The four lithographic plates, drawn by F. Gauthier, are clear and adequate, but from many points of view the inclusion of a few more anatomical drawings, as distinct from general views, of the specimens would have been desirable.

H. L. H.

V.—Laccolites of the Bushveld and Karroo, South Africa.—In some "Further Observations on the Origin of the Rand Banketa" (*S. African Journ. Sci.*, viii, p. 357, 1912) Professor E. H. L. Schwarz compares the type of laccolite of the Bushveld, Transvaal, with that of the Karroo. In the Transvaal a great laccolite of red granite occupies the Bushveld to the north of Pretoria. It is 255 miles long from east to west, and on an average 80 miles broad, although in the central portions the breadth is nearly equal to the length. The body of the laccolite rests on the rocks of the Transvaal system, with the Black Reef quartzites below, the Dolomite above, and the highly ferruginous sediments of the Pretoria Series on top. Into these latter

have been intruded a vast series of sills or dykes of diabase or altered dolerite. The author regards it as inconceivable that such an immense mass of igneous rock should flow over and rest upon the ferruginous and calcareous rocks without absorbing material from them. The Karroo laccolite, formed of dolerite, occupies an area about 700 miles long by 200 broad, while the individual sills are from 100 to 500 feet thick; and Professor Schwarz estimates that the entire material would, if melted up, form a ball 50 miles in diameter. He has no doubt that a considerable amount of sedimentary material has been assimilated. Thus a dyke 100 feet or more thick may have been intruded at a high angle and then bend over to follow the bedding plane of the sediments as a sill. If the dolerite were entirely new material, that had not melted out its cavity, there should be visible above the bend of the dyke to the sill some continuance of the crack through which the dolerite came, but he has seen no evidence of this in the Karroo.

VI.—Geological Survey of the Transvaal.—Memoir No. 6, issued by the Mines Department, Pretoria, 1912, is entitled *The Geology of the Murchison Range and District*; it is by Mr. A. L. Hall, B.A., F.G.S., and is accompanied by a geological map on the scale of about 1 inch to 2⅔ miles. The Murchison Range, which attains an elevation of 2,980 feet, is formed mainly of the Moodies' Series, consisting of quartzites, phyllites, slates, and conglomerates, with ironstones and limestones; and this series presents characters that suggest correlation with the Swaziland system. The Black Reef and succeeding Dolomite Series of the Transvaal system, rest unconformably on the Moodies' Series. The granite of the Low Country is intrusive into the older rocks of the Murchison range, and occupies as regards age a position between those rocks and the Transvaal system. Economically the Black Reef Series and the older Schist belts of the Murchison range are of importance as gold-bearing rocks; there are likewise extensive tracts of mica, some of which occur in coarse white granite pegmatites that are intrusive into the older granite, while others are associated with the newer Palabora granite. Deposits of corundum also occur, but at present it is not possible to estimate the quantity available. More prospecting is required in reference to all the mineral deposits, but the author regards the district as specially suited for small mining enterprises. He further observes that there are remarkably fertile stretches of country with permanent and abundant water and a healthy climate, admirably adapted for agricultural operations.

VII.—Geological Survey of New Zealand.—A quarto volume on *The Geology of the Dun Mountain Subdivison Nelson*, by Messrs. J. M. Bell, E. de C. Clarke, and P. Marshall, forms the subject of an official Bulletin (No. 12, New Series, Wellington, 1911). The area here described lies in the northern part of the southern island of New Zealand, bordering Tasman Bay. The eastern portion, occupied by forest-covered mountains, rises to more than 3,000 feet above sea-level; the western part, drained by the River Waimea and its

tributaries is fertile and highly cultivated lowland. The geological formations are grouped as follows:—

Recent		Alluvial deposits, Travertine, etc.
Miocene . .	Moutere Gravels	River Gravels.
	Jenkins Hill Series	Conglomerates, sandstones, shales, mudstones, limestones, and occasional coal-seams.
Late Mesozoic or Early Cainozoic	Intrusive rocks of "Mineral Belt"	Ultra-basic rocks which pierce the Matai Series.
Trias-Jura . .	Matai Series . .	Conglomerates, breccias, grauwackes, limestones, and argillites, with contemporaneous volcanic rocks.

Among the fossils of the Matai Series are species of *Spirigera*, *Monotis*, *Halobia*, *Trigonia*, and *Gryphæa*. The main object of the work is to describe the nature and extent of the copper-deposits which occur in the Mineral Belt. The associated rocks include peridotites, serpentine, etc., and of these petrological accounts are given. Other economic products of the district are gold, chromite, coal, and building materials.

VIII.—Cambridge County Geographies.—We have received the volume on North Lancashire by Dr. J. E. Marr (Cambridge, at the University Press, 1912, price 1*s.* 6*d.*). It contains a capital account of the physical features, with brief references to the geological structure. The mountains; the fells, some of which are rocky and step-like, while others are peat-covered moorlands; the watersheds and passes, the bare and fissured limestone-tracks known as 'clints', the lakes, tarns, and rivers are duly if briefly described. There appear to be no great forests, but much coppice, and charcoal-burning is carried on for the manufacture of gunpowder. The iron-ore, building-stone, the slate of Tilberthwaite, and rock-salt are among the industries of geological interest. Many good views of scenery are given, and there is a portrait of Sir Richard Owen, who, as a Lancashire man, is rightly given a place with Whewell and Sir Edward Frankland in the section entitled 'Roll of Honour'.

IX.—Brief Notices.

1. Geology of Wyoming.—A memoir on the *Geology and Mineral Resources of a Portion of Fremont County, Wyo.*, has been written by the State Geologist, Mr. C. E. Jamison (Bulletin No. 2, series B, 1911). An account is given of the various geological formations from Pre-Cambrian to Tertiary (Eocene), of their structure and history, with preliminary descriptions of the physical features, climate, and agriculture. The chief mineral products are oil, gold, building-stones, and gypsum.

2. Western Australia.—We have received vol. i, pt. ii, 1912, of the *Records of the Western Australian Museum and Art Gallery*, edited by the Director, Mr. Bernard H. Woodward, F.G.S. In this work Mr. L. Glauert continues an account of the mammalian remains from the Mammoth Cave, describes some "Fossil Marsupial Remains

from Balladonia" and "Permo-Carboniferous Fossils from Byro Station, Murchison District".

3. Molybdenum Ores of Canada.—Dr. T. L. Walker has prepared a "Report on the Molybdenum Ores of Canada" (Dep. Mines, Ottawa, 1911). The ore most widely distributed is Molybdenite: there also occur Molybdite and Wulfenite (molybdate of lead). All information relating to the subject has been gathered, and the author has personally examined many of the Molybdenum deposits.

4. Seismology.—We have received several numbers of the *Bulletin of the Seismological Society of America*, commenced in 1911, under the direction of Messrs. J. C. Branner, A. C. Lawson, and S. D. Townley. While dealing particularly with phenomena observed in America, notices are included of earthquakes in other parts of the world. In No. 4 (December, 1911), Mr. Lawson described some Post-Glacial faults; Mr. J. S. Diller contributes a memoir with portrait of Major Clarence E. Dutton; and there are various articles relating especially to earthquakes, earthquake epicenters, seismographs, etc.

5. Megascopic Pseudostromatism.—Mr. S. Rennie Haselhurst (Univ. Durham Phil. Soc., iv, p. 162, 1912) introduces the term mentioned in describing the larger forms of structure produced by overfolding and thrusting, shearing and cleavage, as developed in shales and micaceous sandstones in the Coal-measures of Northumberland. The characters, which simulate fluxion-structure, appear to be similar to those described by Dr. A. Strahan in the violently disturbed Coal-measures on the Pembrokeshire coast (see *Summary of Progress Geol. Survey for 1905*, p. 60).

6. *Arctotherium* from Yukon.—A new species of this giant bear, named *Arctotherium yukonense*, has been described by Mr. Lawrence M. Lambe (*Ottawa Nat.*, xxv, p. 21, 1911). The specimen, a well-preserved skull, was found at a depth of 40 feet in frozen Pleistocene deposits at Gold-run Creek, Yukon, and the discovery extends the known range of this mammal very far to the north of any previous record. The genus is regarded as intermediate between the old-world *Hyænarctos* and *Ursus*.

REPORTS AND PROCEEDINGS.

Geological Society of London.

June 19, 1912.—Dr. Aubrey Strahan, F.R.S., President, in the Chair.

The following communications were read:—

1. "On the Geology and Palæontology of the Warwickshire Coalfield." By Robert Douglass Vernon, B.A., B.Sc., F.G.S.

The main objects of this paper are to determine the true age of the so-called 'Permian' rocks of Warwickshire, and their stratigraphical relationship to the underlying Carboniferous rocks and to the overlying deposits of Triassic age. Further, the Carboniferous rocks are subdivided into groups, and the age of the subdivisions is determined

from a study of the fossil flora. The results may be summarized as follows:—

TABLE ILLUSTRATING THE CARBONIFEROUS AND PERMIAN SUCCESSION IN WARWICKSHIRE.

Name.	*Characters.*	*Chief Fossils.*	*Thickness in feet.*
PERMIAN.	Calcareous, false-bedded red sandstones, and lenticular red marls spotted with green; with two horizons of Limestone Conglomerates, the lowest of which forms the base.	*Walchia filiciformis* (Schlotheim) *Calamites* sp. *Dasyceps bucklandi* (Lloyd). *Oxyodon britannicus*, von Huene	? 1,000
KEELE BEDS.	Red and purple sandstones and marls, with marly breccias, and, towards the base, beds of grey sandstone. Three thin beds of *Spirorbis* Limestone, the lowest (and thickest) of which is taken as the base.	*Pecopteris polymorpha*, Brongn. *P. arborescens*, Schloth. *P. miltoni* (Artis). *Spirorbis*. Ostracoda.	1,000 to 1,500
HAUNCHWOOD SANDSTONES.	Grey sandstones and shales, with thin coals and some red mottled marls towards the top.	*Neuropteris ovata*, Hoffmann. *N. scheuchzeri*, Hoffmann. *N. rarinervis*, Bunb. *Pecopteris miltoni* (Artis). *P. arborescens*, Schloth. *Sphenophyllum emarginatum*, Brongn.	300 to 450
NUNEATON CLAYS.	Red and purple mottled marls and clays, with thin Espley Rocks, a *Spirorbis* Limestone, and local breccias.	*Cordaites borassifolius*, Sternb. *Calamites* sp. *Spirorbis*. Ostracoda. Fish-remains, undetermined.	80 to 150
MIDDLE COAL-MEASURES.	Grey sandstones and shales, with thick coal-seams and beds of Ironstone Sandstones and breccias towards the top, which thicken to the north. An impersistent conglomerate forms the base.	*Zeilleria delicatula* (Sternb.). *Corynepteris coralloides*, Gutbier *Sigillaria boblayi*, Brongn. *Lingula mytiloides* (Sow.). *Myalina compressa*, Hind. *Pterinopecten papyraceus* (Sow.). *Carbonicola aquilina*, Sow. *Anthracomya williamsoni*, Brown *Naiadites carinata*, Sow. *Megalichthys hibberti*, Agassiz. *Rhizodopsis sauroides*, Willm. *Acanthodes wardi*, Egert.	400 in the south to 700 in the north.

On stratigraphical and palæontological evidence it is shown that a large area of rocks previously mapped as Permian is really Carboniferous.

The Carboniferous rocks are subdivided into groups which, on palæobotanical evidence, are proved to belong to the following three

horizons of the Westphalian Series: the Upper Coal-measures, the Transition Measures, and the Middle Coal-measures; the Lower Coal-measures are found to be absent.

The fossil flora is described in detail, and a brief account is given of the freshwater and marine faunas of the Middle Coal-measures. The Carboniferous rocks of Warwickshire are correlated with those of the other coal-fields of the Midland province, and it can thus be demonstrated that there is a marked southerly attenuation and overlap of each of the subdivisions of the Carboniferous System.

Some account of the Permian and Trias is given, in order to show the unconformable relationship of the Permian to the Carboniferous on the one hand, and that of the Trias to the whole of the Palæozoic rocks of the district on the other.

2. "On the Discovery of a Fossil-bearing Horizon in the Permian Rocks of Hamstead, near Birmingham." By Walter Henry Hardaker, M.Sc. (Communicated by Professor Charles Lapworth, LL.D., F.R.S., F.G.S.)

Some quarries in the Permian rocks in the neighbourhood of Hamstead, near Birmingham, have afforded to the author an interesting series of fossils. These consist chiefly of the impressions of plants, and of the footprints of amphibia assignable to several species.

The quarries from which the fossils have been obtained occur in that broad band of strata which is coloured upon the Geological Survey map as Permian, and fringes the eastern side of the South Staffordshire Coal-field.

The author describes and illustrates in detail the group (and sub-groups) in which the fossil occur, and shows that the group as a whole belongs in its lower part to the Midland Middle Permian (or Calcareous Conglomerate and Sandstone) Division of Mr. Wickham King, and in its upper part to his Upper Permian (or Breccia and Sandstone) Division.

Most of the plants and animal footprints discovered belong apparently to recognizable forms which have been long known to occur in the Rothliegende (or typical Lower Permian) of Germany, and they have little or no resemblance to those of the undisputed Upper Carboniferous of any known area; and the conclusion is drawn that these fossil-bearing Hamstead strata must in future be regarded as of Rothliegende or true Lower Permian age.

On Wednesday, June 26, 1912, a Conversazione, at which about four hundred ladies and gentlemen were present, was held in the Society's Apartments, from 9 to 11.30 p.m. In the course of the evening, two lectures, illustrated by lantern-slides, were given; one on "Tin-Mining in the Federated Malay States", by J. B. Scrivenor, M.A., F.G.S., and the other on "Palæolithic Paintings in the Caverns of Northern Spain", by Dr. A. S. Woodward, F.R.S., Sec.G.S. Many interesting exhibits were shown by various Fellows of the Society.

The next meeting of the Society will be held on Wednesday, November 6, 1912.

MISCELLANEOUS.

The Royal Society.—The Royal Society began the commemoration of its 250th Anniversary, under the presidency of Sir Archibald Geikie, K.C.B., by an evening reception of Delegates and Fellows, on July 15, at Burlington House. On the special anniversary, July 16, there was a good attendance at a short commemorative service at Westminster Abbey, when the Dean, the Right Rev. H. E. Ryle (late Bishop of Winchester), delivered an appropriate discourse. Subsequently there was a formal reception of the Delegates at Burlington House; while in the evening a banquet in the Guildhall was attended by nearly 500 distinguished visitors and Fellows, including the two Archbishops, Cardinal Bourne, the Prime Minister, the Lord Chief Justice, and several Ambassadors. The toast of the Royal Society was proposed by Mr. Asquith, who remarked that the Society "is to-day the most vital, if not the most characteristic, monument of King Charles II"; while Lord Morley, who proposed the toast of the "Universities at Home and Abroad", referred to "the desire to spread the light in a way which would be useful for the social life of the communities and the strength of the cities". Later proceedings, on July 17, comprised visits to places of interest in London, a garden party given by the Duke and Duchess of Northumberland at Syon House, and a conversazione in the rooms of the Society. The celebration terminated on the 18th, when the President and Council of the Society and the Delegates were received by their Majesties the King and Queen at Windsor Castle, and all the Fellows of the Society (with wife or daughter) were invited to an afternoon party in the Castle grounds. The more permanent mementoes of the celebration are the publication (1) of *The Signatures in the First Journal-book and the Charter-book of the Royal Society*, being a facsimile of the signatures of the Founders, Patrons, and Fellows from the year 1660 to the present time—a veritable édition de luxe, issued in imperial quarto; and (2) of a third edition of *The Record of the Royal Society*, a handsome volume in crown quarto (pp. 483). This work has been edited by the President, who has rewritten the first chapter which contains a narrative of the Foundation and Early History of the Society. The Chronological Register and Alphabetical List of Fellows has been revised, and now includes all names from the year 1663 to May, 1912. There are views of old Gresham College, and of the residences of the Royal Society in Crane Court and Burlington House. The portraits are of King Charles II, Robert Boyle, Sir Christopher Wren, John Evelyn, Sir Isaac Newton, Sir Hans Sloane, Benjamin Franklin, Thomas Young, Sir Humphry Davy, John Dalton, Michael Faraday, Lord Kelvin, Lord Lister, and Charles Darwin. The earlier editions of the Record contain other portraits and illustrations of medals not here reproduced.

International Geological Congress.

The twelfth session of the Congress is to be held in Toronto, Canada, and will continue for eight days, beginning on or about

August 21, 1913. H.R.H. the Duke of Connaught, Governor-General of the Dominion, has consented to become Honorary President. Fuller particulars relating to arrangements will be issued later. Meanwhile the Executive Committee, with Professor F. D. Adams, F.R.S., as President, have been making arrangements for a series of excursions before, during, and after the meeting of the Congress. These will be planned so as to afford an insight into the geology and physiography of Canada, including the mineral and other natural resources of all the more accessible portions of the country.

The following topics have been selected by the Executive Committee as the principal subjects for discussion at the Congress:—

1. The coal resources of the world.
2. Differentiation in igneous magmas.
3. The influence of depth on the character of metalliferous deposits.
4. The origin and extent of the pre-Cambrian sedimentaries.
5. The sub-divisions, correlation, and terminology of the pre-Cambrian.
6. To what extent was the Ice Age broken by interglacial periods?
7. The physical and faunal characteristics of the Palæozoic seas with reference to the value of the recurrence of seas in establishing geologic systems.

Correspondence should be addressed to the Secretary, International Geological Congress, Victoria Memorial Museum, Ottawa, Canada.

The Stuttgart Mammoth.—There has just been mounted by Dr. Eberhard Fraas for exhibition in the Royal Natural History Museum, Stuttgart, a specimen which may certainly be regarded as the largest nearly complete mammoth skeleton yet discovered.

In August, 1910, there were found at Steinheim, in the diluvial deposits of the River Murr, a tributary of the Neckar, in Swabia, a number of fossil bones indicating the remains of an unusually large mammoth. As a proof of its size it may be noted that the skull weighs nearly three-quarters of a ton, and the height of the skeleton is over 13 feet.

The specimen is remarkable for the abnormal length of the legs: probably it was a swift-moving animal; and for a degree of general lightness of frame, indicating activity. The tusks are well shaped with a slight semicircular curve, but are much less in size than the normal type, being only $7\frac{1}{2}$ feet in length, whereas many of the Siberian and American specimens have tusks double that size. These features lead naturalists to regard it as belonging to a late type of mammoth when the transition to the smaller and more active elephants was commencing.

It is so fine a specimen that it is to be hoped that casts of at least the most important portions of the skeleton may be obtained for our Natural History Museum in London.

We regret to record the sudden death of the Rev. Robert Ashington Bullen, B.A. (Lond.), F.L.S., F.G.S., F.Z.S., F.R.A.I., Memb. Malac. Soc., of Hilden Manor, Tonbridge, Kent, when crossing to Germany by the Calais night mail boat on August 14. He was interred at Brookwood on August 20. We hope to publish an account of his work next month.